

The
PLAYFUL
World

HOW TECHNOLOGY IS TRANSFORMING
OUR IMAGINATION

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BALLANTINE BOOKS | NEW YORK

1 : FURBY FABLES

BATTERIES NOT INCLUDED (BUT A DICTIONARY IS)

"Me love *u-nye*."

A startling moment: when I get the four AA batteries into the casing, just as I tighten the screw, my little tiger-striped friend begins to chirp away. I almost drop it. It squirms in my palm, and I feel as though I've just done some veterinary surgery. Or perhaps some robot repair. Should I have used an anesthetic?

I consult the dictionary. *U-nye* means "you." "I love you," it's saying, perhaps grateful for the newly supplied power or delighted at the stimulation.

All of six inches tall, my new friend has a black mantle sweeping down its backside and a white belly that just cries out for a nice scratch.

"*Koh-koh*, please." He likes it and wants me to scratch him again. "Again," he says. And once more. Now he seizes the initiative and says, "*Kah a-tay*." He's hungry—well, it is close to lunchtime—so I gently open his beak and depress his tongue. "Yum. *Koh-koh*." I feed him again, per his request. And once more. Now he buzzes with the android equivalent of a gastric embarrassment, and says, "*Boo* like." He's a little fussy and doesn't want to be overfed. No like.

A moment later, he's happy enough, and sings a little tune. "Dee-dee-dee-dee-dee, dum-duh-duh-dum." Just in case he's

said something important, I check the dictionary, but it's only a melody, a playful pause. So I pick him up, as I would with a small child, and send him flying through the air, carefully guided by my hands, doing cartwheels and somersaults and flying leaps. "Wheee!" he exclaims, and this needs no translation. My little friend expresses pure delight, giggling.

Back on the table, he sits while I make some notes. But he's a child in every sense of the word. Not content to let the world go by, he constantly interjects a bit of song or a few words; finally, after his repeated interruptions have been ignored, he pronounces the situation "boring."

My friend is really quite demanding. He wants to play, to enjoy my company, and he'll complain if he doesn't get all the attention that is his due. But I have words to write about him (though he doesn't know it), so he sits on the table, beside my computer, and continues to speak.

Finally I lean over his left ear, a broad black-and-white leaf that extends far past his body, and say, "Hello, my friend."

"*Kah-dah boh-bay*," he replies, startled. Translation: I'm scared. I guess I spoke a bit too loud. I pet him a bit, and he responds with a few sighs of pleasure. Then he goes back on the table. "Boring," he pronounces once again. He really *does* want 100 percent of me. Anything else and he'll act childishly petulant. This time he makes exaggerated snoring sounds. But I leave him alone. I have work to do.

Then my electronic friend sings the first bars of Brahms's Lullaby and goes to sleep.

THE HOTTEST TOY IN THE WORLD

The scene, repeated over and over, always went something like this. A harried parent, having made his or her way to an overcrowded shopping mall, fought through the stream of other, equally harried parents at Toys 'R' Us or Kay-Bee Toys or FAO Schwarz.

He'd pass stacks of Barbies and G.I. Joes and Tickle Me Elmos with a single goal in mind—a tiny furry talking toy. He could see the display, but as he approached, he found the shelves bare. In every store, on every website, the same sad tale.

In October of 1998, the Amazing Electronic Furby joined that rare class of toys which transcend mere popularity to become objects of fascination, cultural landmarks that tell us what our children are really drawn to. The Furby, from its introduction at the New York Toy Fair, caught the imagination of toy buyers, retailers, parents, and children across the United States, who collectively turned a little electromechanical gizmo into a bestseller.

Why? The rotund, wide-eyed furbal is designed to be cute—sort of a cross between an overfed hamster and Gizmo from the film *Gremlins*. As a plush toy, it would have had a certain degree of success, popular with the under-ten set. But once four AA batteries have been put into its plastic bottom, the Furby comes *alive*—a yammering, demanding being who hungers for affection, food, and companionship.

Over a hundred years ago, Thomas Edison invented the first talking toys, adapting his mechanical phonograph to produce a pull-string doll that could recite a few prerecorded phrases. Over the twentieth century, toys grew more and more verbal, but still required some action on the part of a child, such as pulling a string, to produce a reaction. In 1980, calculator manufacturer Texas Instruments introduced the Speak and Spell, a high-technology wonder using microprocessor technology, together with voice synthesis, to teach children the alphabet and talk them through basic spelling exercises. With the Speak and Spell, the tables had been turned; now the toy took the active role; the child listened and reacted to it.

When the world of computers intersected with the world of toys, the concept of interactivity, of two-way communication between toy and child, ushered in a new universe of possibilities. Now toys could listen to children, observing patiently as they

worked at various spelling exercises or games, and react to them personally, like a watchful parent, constantly assessing performance, gently extending the boundaries of the child's knowledge. This reactive intelligence produces something greater than the sum of its parts; the child often feels more engaged, and so works—or plays—harder.

This delicate dance between toy and child, now some twenty years old, has yielded only a few out-of-the-park success stories, most of these in educational toys, which drilled the child in various skills. Teddy Ruxpin, a mid-1980s toy dreamt up by Atari founder Nolan Bushnell, the father of pop interactivity, used sophisticated animatronic circuitry to bring a classic teddy bear to life. But Teddy Ruxpin hardly responded to the child, and while it could read a bedtime story to a toddler, it couldn't allow the child to participate in the storytelling. Though vastly more sophisticated (and expensive) than Edison's first talking dolls, it remained essentially a one-way device: Teddy spoke and the child listened.

The adventurous child can exhaust the limited possibilities presented by these so-called interactive toys in a few hours of play. Once the repertoire of activities has been explored, the toy ends up discarded, ignored. It holds nothing new for the active imagination, and the child moves on.

What if a toy could evolve, grow, and respond to the child, then demand that the child respond to it in turn? By the mid-1990s, such ideas, variants of which had been floating around the computer science community for several years, began to show up in a few different toys. The breakthrough product, however, was a watch-like device developed by Japan's Bandai Corporation, called Tamagotchi.

Billed as a virtual pet, the tiny device used a miniature LCD screen, similar to those found on most cheap wristwatches, to illustrate the life-state of the virtual pet contained within it. A Tamagotchi is born when it is first turned on by its owner, and

thereafter it reacts much like a growing pet, requiring food, attention, and sleep. (Each of these virtual stimuli could be delivered through a few presses of a button on the face of the device.)

As the Tamagotchi grows up, it begins to mature, requiring less sleep, more food, and more playtime with its owner. If you forget to feed it, it will grow irritable and might even die. (When this happens, its iconic character on the LCD screen sprouts wings and flies off to heaven!) If you don't play with it, it will become ornery, just like any pet neglected by its owner. Fortunately, it will beep at you to indicate that it wants some food or just some attention. You can choose to ignore it, but that choice comes with a cost. *Here* was a concept that had never been embodied in a toy; unlike the animated playthings that had preceded it, the Tamagotchi could make demands and respond to neglect. Actions would have consequences.

Tamagotchi was a huge hit, first in Japan, and then worldwide, with the eight- to fourteen-year-olds, mostly girls who pinned them to their backpacks or belt loops or blouses. By engaging their desire to nurture, Tamagotchi gave these children an outlet they had been able to express only in the inert world of dolls. Barbie doesn't care if she's left alone for a month, but a Tamagotchi will likely expire if left alone that long. This simple fact had a profound psychological impact on these girls, who came to regard the toys as something nearly alive; less demanding than an infant human and certainly more portable than a puppy, but just as full of needs and programmed with the desire to engage them, an emotional manipulation more effective than any toy that had come before it.

A virtual pet, trapped inside a small plastic shell with a minimal display, could strike the fancy of an imaginative preteen, but wouldn't it be far better to create an entire, physical creature that could embody the principles of Tamagotchi? A real, physical toy could capture the hearts of younger children—along with older

ones. Much of play is based in touch, in the feel of the real, and while Tamagotchi engaged the mind, it couldn't play with a child in any real sense.

Watching pet hamsters skitter across a bathroom floor, a designer named Caleb Chung began to conceive of an idea for a furry electronic pet, something that could take the simulation of Tamagotchi and make it real. After careers as a comic and a mime, in his late thirties Chung turned his prodigious talents toward toy design, and became a modern-age Geppetto, able to breathe the semblance of life into plastic and a few motors. Noting the explosive popularity of Tamagotchi, Chung reasoned that with a little work and some significant improvements, the virtual pet could become a real toy.

Roger Shiffman of Tiger Toys thought so, too. Over twenty years Shiffman and his partner Roger Rissman had built the Chicago-based toy manufacturer into a successful business, thriving even as their competitors went bankrupt or were acquired by toy giants like Hasbro and Mattel. They had scored a modest hit with Giga Pets, which resembled Tamagotchi in that a virtual pet expressed itself through its meanderings across a larger LCD screen. Like Tamagotchi, Giga Pets required the constant care and attention of their owners, displayed various needs, and responded to affection. However, Giga Pets were based on real-world animals, with names such as Digital Doggie and Compu Kitty, and behaved more like their namesakes; the on-screen dog could play fetch and the cat could wrestle with a ball of string. The toys presented the most salient features of each of their flesh-and-blood counterparts, but made them portable, manageable, and nearly as friendly. Still, locked inside their plastic casing, Giga Pets couldn't reach out to touch a child's heart in the same way that a pet or even a plush toy could. Software just doesn't feel real, especially to a small child.

So when Chung approached Shiffman with a prototype of the Furby, the stage was set for a revolution in interactivity, a vir-

tual pet made flesh. Through a lightning-fast development cycle (most toys take at least two years to reach market, while Furby went from prototype to product in less than ten months) the team at Tiger Toys (and Tiger's new parent, Hasbro) found a sweet spot of interactivity and affect that charmed everyone—including its creators. Alan Hassenfeld, the president of Hasbro, loved Furby from the first moment he set eyes upon it, pronouncing it the coolest thing he'd seen in twenty-five years in the toy business. Media outlets from *Wired* to *Time* chimed in with their own rapturous opinions, and the vortex of hyperbole reached a frenzy on October 1, 1998, when Furby was officially unveiled at FAO Schwarz's flagship store in Manhattan.

Tiger Toys planned to manufacture a million Furbys for the Christmas season. Most of them had already been purchased, months before, by big retail outlets such as Wal-Mart and Toys 'R' Us. They sold out immediately everywhere they were placed on display. The \$70 million advertising campaign that Tiger orchestrated seemed almost a waste of money. At \$30, the toys were selling themselves. Parents couldn't refuse their child the hottest toy in the world.

That is, if they could find one. The shortage immediately spawned a black market in Furbys. Classified ads in the *Los Angeles Times* offered Furbys in several attractive colors for \$200 apiece. In the online auction at eBay, bidding sometimes went as high as \$400. Buyers spent a chill evening massed outside of a toy store in Santa Monica when it was reported that a shipment of five hundred Furbys would be released the next morning. Rumors of soon-to-be-released caches of Furbys flooded the Internet. Demand seemed insatiable. For every Furby unwrapped on Christmas morning 1998, four more could have been sold in its place.

Furby had struck a chord.

I'VE GOT FURBY UNDER MY SKIN

Furby's success represents more than just a fad. The Furby is the best example of a new class of toys—reactive, verbal, and engaging. While Tamagotchi and Giga Pets pioneered the virtual pet, Furby represents the first real outpost on the virtual frontier. To understand why, we need to lift the skirt of a Furby and find out what makes it tick.

Within a few weeks after Furby's release, hundreds of Furby fan websites sprung up. One of the most interesting of these is the Furby Autopsy site. Dedicated to the memory of Toh-Loo-Koh, a Furby who passed away under suspicious circumstances (which are never fully explained), the authors of this site decided that their recently deceased Furby should live on, in the interests of science, as an anatomical study of the animatronic toy.

Only a few stitches connect the Furby's fur to the plastic case that houses its electronic and mechanical components. Once these stitches have been cut, you can remove the fur by rolling it up to its head. Next, the fur covering its ears must be carefully released, and finally the entire furry surface can be pulled over the Furby's head. Now you have a skinned Furby, with its innards exposed.

If you're brave enough to complete this operation—without losing your lunch—you'll now see a small, almost cubic block, densely packed with gears and electronics. This is the real Furby, a robot with Ping-Pong ball eyes and a circuit board for a diaphragm. The authors of Furby Autopsy describe the gear and cam system, which activate all of Furby's moving components, as a work of genius, simplicity itself. A single driveshaft controls all of Furby's motions, unlike Disney's animatronic monsters, which have thousands of independently moving parts. Various rotations of the driveshaft control different activities, such as blinking the eyes, dancing, or wiggling its ears.

The motor turning the driveshaft is mounted on a printed cir-

cuit board, similar to those found in other consumer electronics, such as a Walkman, and is itself controlled by a host of electronic components also located on the board. This is the real source of Furby magic, where its complex programming produces a simulation of life.

All interactive toys must have at least two different types of components: sensors which allow the toy to know what is happening in the environment around it, and effectors, which allow it to respond to the environment. There are sensors to mimic every sense that we possess: light sensors, microphones, switches that turn on or off when tilted (a sense we have in our inner ears), pressure switches (which sense touch, much like our skin), and so on.

The Furby doesn't completely duplicate the innate human senses (for example, it can't taste or smell), but it can sense light and dark: a third eye located above its peepers detects light sources. It can hear sounds through a microphone located within its left ear, and it can be tickled or petted by means of pressure sensors located on its stomach and its backside. Finally, a tilt sensor located behind its extra eye lets it know if it's upright, being tipped upside down (which is how you wake a Furby after it's gone to sleep), or just being somersaulted through the skies.

All of these sensors are wired into a set of microprocessors contained on the circuit board. As the signals from each flow in, they're sampled for their current values and then fed into a complex computer program that brings the Furby to life. While the mechanical design of the Furby may be genius, the Furby's program is the real work of art, carefully crafted to make the creature seem as lifelike as possible, given its limited capabilities.

A conservative estimate of the Furby's brainpower puts it at one ten-billionth of our own human capacity. Why, then, does it seem so alive? Because it plays upon human psychology, our desire to anthropomorphize—to see the inanimate and nonhuman as human. We do this all the time: look at how people behave

toward their beloved cars or boats or computers, treating them as people, with feelings that can be hurt. Yet these devices don't respond to that affection. The Furby does, using two techniques—facial expressions and its verbal ability—to create the illusion of real life.

Over the last few years, researchers working in the field of cognitive science have begun to discover just how important facial expressions are to human beings. It seems as though we're able, from the moment of birth, to recognize facial expressions on those around us. This instinct probably helps mothers to bond to their children and helps children recognize their caregivers. It also allows mothers to recognize and respond to their children's physical and emotional states long before the children can express these verbally. People often note a mother's uncanny ability to read the mind of her infant; in part, she's interpreting facial expressions.

The Furby can produce faces that look a lot like wide-eyed wonder, anger, sleepiness, and playful joy. We don't need to learn what these expressions mean; they're reflections of our own innate understanding. When we encounter them, we immediately believe that these expressions imply a human-like depth to the being or toy displaying them. It's all in our own minds, just an illusion of humanity. But that doesn't seem to matter. Our emotions carry us away, and it becomes easier to believe that Furby is alive.

With the probable exception of whales and dolphins, human beings are the only species blessed with a verbal consciousness, the ability to translate the details of our thoughts into oral communication. Many animals communicate, to find mates or warn others against predators, but no other species has been shown to communicate so broadly (and about such trivia) as human beings. It's one of the things that makes us human. To be human is to live in near-constant communication.

Of all of the Furby's affectors, the most indispensable may be

its voice box. Although it simply plays prerecorded sounds, the Furby has an ability with language unlike any toy that came before it. Furby has a built-in vocabulary of a few hundred words, many of them in a homegrown language known as Furbish. But rather than just uttering single words or canned phrases, the Furby has programming that allows it to combine these words into a pidgin—a simplified, bare-bones language similar to others that evolved in the multilingual trading ports of the South Pacific in the seventeenth century, where Portuguese and English mixed with a hundred native tongues. This stripped-down syntax allows a Furby to utter at least a thousand different phrases of all types.

While not exactly encyclopedic, a Furby's repertoire of sayings fairly replicates the linguistic abilities of a child in its first years of speech. Its ability to voice its needs and desires gives Furby an implied depth. The subconscious mental calculation goes something like this: only humans speak; only humans can take language and twist it into new forms; therefore anything that can use language like a human must be (nearly) human. When Furby's voice is combined with its range of facial expressions, it becomes easy to see why people take to it instantly: it seems real enough to be human, to be accorded the same depth we grant other people. It seems a worthy object of affection. Children give their affections broadly, but adults tend to be much more circumspect; and yet Furbys capture the hearts of adults as readily as they do children.

What do Furbys talk about? This is perhaps the most interesting and lifelike aspect of the toy, because Furbys have *needs*. Like the innards of Tamagotchis and Giga Pets, Furby's software has been crafted with a sense of purpose, of requirements that must be met in order to keep the Furby healthy and happy. For example, a Furby must be fed on a regular basis—not real food, but rather, by opening its yellow plastic beak and depressing its tongue. A Furby almost always responds with a "Yum" when fed, and though it might occasionally break wind if it's been overfed,

it needs to be fed daily or it will catch a cold. (It's true: the Furby will lapse into near-continual sneezes if it's been consistently underfed.)

Once its appetite has been sated, the Furby wants what almost any pet wants—the attention of its owner. It might ask to be tickled or to be taken to bed and told a story. Because of its sensors, it knows when it is being stroked or read to and can respond in kind. (Furbys don't understand English, though, and can't respond to the details of a story. That's a possibility reserved for science fiction, and perhaps some toys of the future.) The Furby has a soul whose essence is play; its greatest delight, as judged by the sounds it makes and the expressions upon its face, comes when it is deeply involved with and responding to a child.

Furbys *evolve*. Though this may seem a ridiculous claim to make for a mechanical device, an important part of the Furby's programming concerns its evolution, and a memory of its own interactions with its owner. When a Furby is first brought to life, it speaks a patois comprised mostly of Furbish, with only a few English words. But as the Furby grows older—that is, after it has been played with over a period of time—more and more English words work their way into its vocabulary—just as you might find happening in a child during the transition from baby talk to intelligible verbal communication. Although this evolution was an easy thing for Furby's programmers to create, it adds a certain depth to the experience of owning the toy. Like a real pet, the Furby remembers its interactions with its owner, particularly those activities that bring delight to its owner. (This is easy to determine: if a child likes a certain activity, he or she will repeat it. Endlessly.) As it grows up, the Furby is more prone to engage its owner in the behaviors that bring the two together joyously. And since each owner has a unique set of likes and dislikes, no two Furbys will evolve along the same lines. By the time it's fully mature, each Furby is a reflection of its owner, a combination of

mechanisms, programming, and evolving behaviors that together produce a compelling simulation of real life.

Finally, *Furbys can learn from each other*. That mysterious third eye located above its orbs contains a light sensor, but it also contains an infrared transceiver similar to what you might find in a television remote control and the television it's controlling. When Furbys are placed in proximity with each other, they can communicate silently, using invisible pulses of light. This is the equivalent of a Furby local area network, and all Furbys within the line of sight will likely begin a group conversation, asking each other to dance or playing a learning game where each teaches its peers some phrases of a song. This only adds to the perception that there's something under the skin, a consciousness very much like our own.

Of course, it's all an illusion; the Furby is not conscious, at least not in the way we think of ourselves as being conscious. But the Furby provides enough of a vehicle on which we can project our own ideas of what constitutes a human being that it's very difficult not to treat them as real entities, with feelings, needs, and desires.

Is there any doubt about why they've suddenly become so popular?

MAN'S BEST FRIEND

After Christmas came and went, and a million lucky children had unwrapped their Furbys, stories about the little toy began to work their way into the media. It wasn't enough that the Furby had become the object of desire for so many holiday shoppers; the world's fascination lived on. As people grew more attached to their Furbys, they told or read stories about them, and as each tale reached another set of ears, a whole new set of myths grew up. A few of these stories made it into the media; they paint a

picture of how the Furby captured the hearts and minds of children across America.

In early January, as people went back to work, CNN reported that the National Security Agency had banned the playful pal from their Maryland headquarters as a security risk. It seems that the NSA believed that the Furby had the ability to record sound—just a second or two—from the microphone embedded in its ear. This, reasoned NSA officials, made it possible for Furby bearers to smuggle state secrets off the premises. Recording devices are banned in the halls of their super-secret Fort Mead center, and employees are searched as they enter and leave the facility. When Furbys began to show up on employee desks, they were ignored as just a toy—for a while.

Before long someone at NSA security learned of the Furby's microphone, and from this surmised (incorrectly) that the device could record human speech. Imagine spies feeding their secrets into the seemingly harmless pets. Furby could be a fifth column that might jeopardize American security! So a directive came down from NSA officials stating that "personally owned photographic, video, and audio recording equipment are prohibited items. This includes toys, such as 'Furbys,' with built-in recorders that repeat the audio with synthesized sound to mimic the original signal. We are prohibited from introducing these items into NSA spaces."

Tiger Toys immediately issued a statement declaring that the Furby, while it could "hear," couldn't record sound. But the idea of a traitorous Furby had caught on, and soon after the NSA ban, NASA's security office announced a similar prohibition. It all seemed like a case of the bureaucratic willies, brought on by an enormously engaging toy of unknown capabilities, the perfect background onto which people could project their own fantasies, pleasant or paranoid.

NSA employees, upset at being deprived of playtime with their animatronic pets, began to complain on the agency's electronic

mail and bulletin board systems. "Damn! Next they'll tell me my rubber ducky has to go," quipped one. Others wondered what all the fuss was about, saying, "I don't think we have a problem with nonemployees wandering into NSA with a Furby 'under their coat.'" As the controversy grew, embarrassed NSA officials issued a final statement, "Please cease and desist posting on this topic immediately," thus summarily ending all discussion.

To this day, no one has been able to demonstrate that a Furby can record sound, but the NSA ruling stands. Just in case.

A few weeks later, another story appeared on CNN's website, this one scooped from the pages of the *National Enquirer*, that bastion of fair and accurate news reporting. A tale that would normally have been ignored by the mainstream press—bizarre as any alien abduction or three-headed baby—was picked up and broadcast *because* it involved the Furby.

Here's the report in full from the *Enquirer*:

Fire! Furby Saves Soap Star's Life

Former "Young and Restless" actress Candice Daly and her boyfriend were saved from a fiery death by her Furby doll!

"We call him our little angel now," declared comic Quentin Gutierrez, boyfriend of Candice, who played Veronica Landers. "That Furby saved our lives."

Quentin sprang out of bed when the Furby, a Valentine's Day present for Candice, started squawking at 3 a.m., and he found a chest of drawers in flames!

"Earlier Candice and I had dinner, drank some wine and fell asleep. We forgot all about candles we had left burning," the 37-year-old comedian told *The ENQUIRER*.

Candice loves that Furby and loves to sleep with it, and thank God she does! The Furby goes to sleep when it's dark and wakes up and starts to talk when the lights come on. It makes noise like a rooster crowing.

"The light of the flames woke up the doll and it started talking.

"It kept yelling 'Cockadoodledoo' and talking baby talk, and I

finally woke up enough to look around, and I saw the flames! A candle had burned down and set fire to a chest of drawers. We were only seconds away from a devastating fire which would have killed us both!

"My two fire alarms didn't make a sound, but Furby was a real life-saving hero! I grabbed some underwear and smothered the fire.

"He's the greatest toy on earth!"

Every quality attributed to the Furby by the *Enquirer* article is in fact true. (Yes, folks, some of the facts reported in the *Enquirer* aren't made up. I'm as surprised by this as you are.) The Furby will go to sleep when the lights go down (remember, it has a light sensor in its third eye), and in the morning, when light returns, it will wake up with a Furbish "Cock-a-doodle-doo!" So, in fact, it is possible that this incident did occur, that Candice Daly's Furby did save her life, and the life of her quick-to-react boyfriend Gutierrez. Which is probably a first, both in the brief history of the Furby, but also in the much longer history of toys.

It rates barely a yawn when we hear a stirring story about how a faithful dog saves its master's life from a fire, intruders, or some other disaster. Man's best friend has a long tradition of taking care of us—even as we have taken care of them. It's the bargain we worked out many thousands of years ago, when we first domesticated these cousins of wolves. Within a few weeks of its arrival, people were willing to cut Furby in on the deal, at least theoretically.

If a creature could respond to you, could talk to you in your language (or, if you cared to learn it, its own), and generally act as best friends for life from the moment you popped in its batteries, perhaps it could rival the flesh-and-blood pets for the role of human companion. An intriguing idea which, though left unsaid at the time, must have been floating around in the public mind as this report reached the airwaves. And if this report had talked

about any other toy besides the Furby, it would have been dismissed as ridiculous. (It might have made it into the *Enquirer*, but CNN? I think not.) But in the brief span between October 1998 and February 1999 so many of our own human qualities had been applied to the Furby—more anthropomorphizing—that they seemed nearly human, and certainly far more intelligible than dogs or cats.

The nation had a new pet—and a new protector.

The last of these stories is by far the most serious, and leads us into a deeper discussion of the meaning and future of the Furby, because it directly addresses the essential human relationship the Furby plays upon to produce its intoxicating effects. On July 6, 1999, Wired News, which had earlier hailed the Furby as a revolutionary toy, reported that a woman from Blacksburg, Virginia, claimed her son's Furby had taught him at least half a dozen new words.

This wouldn't be an outstanding claim in any normal circumstance; toddlers pick up words wherever they are uttered, but Lisa Cantara's son, C.J., is mildly autistic. Although much remains a mystery about autism, it is known that autistics have trouble building relationships with people (or pets), that they acquire language very slowly, and that they thrive on repetitive behaviors. (Where a normal child might tire of some behavior after the thirtieth or fortieth go-round, the severely autistic might still be deeply interested well into the thirty- or forty-thousandth.)

For an autistic child, the Furby might be an ideal pet; it speaks to a child in English, might even inspire that child to learn Furbish, and enjoys constant, repetitive stimulation, never growing bored with the attention. Cantara was quoted as saying, "It increased his vocabulary and helped his speech. He started saying 'I'm hungry,' instead of just 'Hungry.' The Furby taught him that."

She noted her son's rapid improvement in language skills after he was given the toy. "He became very attached to it. He carried

it around with him everywhere and started to mimic it. He talked to it a lot. He treated it like it was a real creature." Despite his difficulty connecting with other human beings, C.J. was able to establish a bond with the animatronic pet. Through repeated interactions, the Furby was able to improve C.J.'s communication abilities with others. "I only wish I could get Furby to say more words," Cantara wrote to an online bulletin board of Furby hackers—people who, like the creators of *Furby Autopsy*, take their Furbys apart to better understand what makes them tick. Cantara pleaded with them for help. "It's been a great learning tool for my son, as odd as it might seem."

In fact, by midsummer 1999, similar reports were streaming into Tiger Toys' Chicago headquarters. The odd had become commonplace. In the same article, Tiger Toys spokeswoman Lana Simon commented, "It's a really magical toy. We've heard from the parents of handicapped children and nursing homes, where they've been given to Alzheimer's patients. I've heard of them causing reactions in people that otherwise show no movement. It registers with them, it stimulates them."

The magical Furby, which mimics human behaviors through facial expressions and vocalizations and which portrays at least a fair simulation of consciousness, seems to be able to connect with people who would otherwise be disconnected, cut off from the human world, because of infirmity or circumstance. It gives people the companionship of a pet without all of the allied responsibilities, and it provides an English-speaking counterpoint to their quiet lives. People who couldn't manage a dog or cat can easily play with a Furby, to the delight of both. Furby feigns the same interest and delight and makes some of the same demands (though with a much lighter burden). Just as pets have been proven to help people maintain their contact to the world at large, the Furby works the magic of relationship to create a healthier, happier person.

We know that children need toys to stimulate their imagina-

tions, to help them along the flights of fantasy that will lead them to determine their likes and dislikes, their social skills, and even their choice of careers. Adults often consider themselves above toys; in fact, a line in the Bible speaks directly to this: "When I was a child, I talked like a child, I thought like a child, I reasoned like a child. But when I became an adult, I set aside childish ways" (1 Corinthians 13:11). It's almost an embarrassment for an adult to admit a fondness for a children's toy—beyond a nostalgia for toys of the past, that is. But Furby seems to have transcended the category of toys for children, and as a faithful and loyal companion, might be on its way toward a permanent place in our culture. The way it engages us, the needs it seems to satisfy, tell us something about ourselves and about the future of our relations with the artificial world. Furby is a starting point, a launching pad into a new tale of the long story of man and machine.

In order to understand where Furby is going, what it might look like by the time our millennial child has reached her sixth year, we need to rewind the tape of history just a bit, and understand how the development of artificial intelligence will inform the future of the Furby. From a study of a toy we'll transition to a story of big science, to see how each converges upon the other.

4 TINKER'S TOYS

HIP DEEP

"Click the play button *now*."

Click.

"To give instructions to your robots you will use a programming language called RCX Code. After creating your program, you will download it to your RCX. The RCX is the brain of your robot.

"To begin, open to pages 13 and 14 and build the Pathfinder One robot . . ."

My computer is talking to me. Not altogether rare in an age of interactive media. And, because it has encouraged me deep into a complex task, it gives me detailed instructions, encouraging words, and helpful images, doing its best to aid me.

The hardest part of the whole operation seems to be finding the correct pieces to complete the job. There are hundreds of little plastic parts (nearly a thousand!) in shiny grays, blacks, yellows, whites, and greens. It's all a little daunting, but eventually I realize I simply have to dunk for parts, diving hand-first into a dozen trays, bringing up a clutch to be eyed and sorted for the proper components. It takes a few minutes—in fact, longer than I really wanted to spend on the task—but as I progress, I begin to remember how much fun I used to have doing this.

As you can probably tell by now, I was one of those kids who

loved Legos. Together with Hot Wheels and Tonka trucks, Legos made up a lot of the imaginary play space of my childhood. I spent hours deep in the construction of fantastic shapes: spaceships and houses and a whole host of other things I couldn't name. But I could take my imaginings and make them concrete, one brick at a time.

I always preferred the generalized Lego sets to the custom kits with the pieces for an automobile or a firehouse. Perhaps I wanted to discover the designs for myself. Creativity seemed to be the whole point, more involving than the assembly of some predesigned product. But now I find myself seated in front of a very specialized kit of Legos. This set will allow me to build *my own robots*.

All of this talk about robots and intelligence has gotten me itching to build a robot of my own. During the research phase of this book I came to understand that artificial intelligence is a sport that nearly anyone can dabble in—if you have the right equipment, that is. Now I've realized that I do indeed have the right equipment here in these boxes, potential resting in a multitude of plastic pieces. Cool.

Eventually, I do find all of the correct parts and snap them together according to the detailed photographs given in the *Constructopedia*. First the frame, then two motors, right and left, then the wheels—yellow hubs popping into rubber tires—gently pushed onto the shafts protruding from the motors. Now I add the power cables, which look like a pair of thin 2×2 Lego squares with a wire running between them, attaching them to the power plugs atop the motors. For the final stage, I take the RCX, the brains of my robot, and place it on top of the body I've constructed. It's about four inches on a side, and weighs half a pound, so it takes a moment of wiggling before I hear it snap into place. Now I take the unattached end of the motor power cables and attach them to the RCX, onto squares labeled "A" and "C." Okay, I'm done. But what does it do? What have I built?

"In training mission one, you will create a program to make your robot move away from you for one second, and stop.

"You will create programs by stacking code blocks that fit together like puzzle pieces. On the left side of the screen you will see four different-colored blocks. Each block is a menu. The **Commands** menu contains blocks to tell your RCX to turn motors on and off. **Sensor Watchers** contains blocks to tell your RCX how to respond to touch and light . . ."

I'm beginning to get the picture now. It seems that the Lego metaphor of bricks snapping onto bricks has been extended into the bits of software that will make my robot strut its stuff. This idea of component software has intrigued computer programmers for many years, but has only rarely resulted in anything usable. Most programs are too different, one from another, to be composed out of a heap of basic elements. A well-written program is like a poem, each element in a precise position that creates, in the eyes of other programmers, its essential elegance.

Such elegance is rarely learned in a week or a month or even a year. Most practitioners of the software arts take five to ten years before they've really mastered their craft—very much like the medieval concept of a trade guild and its stages of apprentice, journeyman, and master craftsman. Much of that time is spent learning the pitfalls of programming, by falling into numerous logical holes and endless loops. It's not that software is intrinsically hard, but it can get complex quickly. You really need to think about the problem before you begin. And this is what separates the seasoned programmer from the neophyte: experts think long and program little, while beginners do just the opposite, hacking their way to a solution, like an explorer clearing a jungle path with a machete.

You have to be pretty dedicated (or pretty crazy) to master computer programming, so most people shy away from it, a bit of "rocket science" many doubt they could master. But anyone can play with Legos. They're obvious, even to a child. And that's the

secret of this software. Using the metaphor of the Lego brick, people should feel right at home snapping a program together.

A few moments later, I have snapped together three green virtual blocks on my screen, which I grabbed from the Controls menu, like fishing Legos from a bin. The first is labeled "On," the second, "Wait," the third, "Off," all stacked from top to bottom, just like a tiny tower. Of course, this is only a representation of the program. I have no idea what commands my Legos actually understand, nor do I have any need to know. But I do need to get these commands into my robot, so I press the button labeled "Download" with my mouse and move my little robot near the four-inch tall black-and-gray tower which I have connected to a port on the back of my computer. A green light glows from the tower, which tells me it's using infrared signals to talk to the robot, much as the Furby uses them to talk to its peers. Then my robot emits a melodic beep, and I know we're ready to roll. Literally.

I place the toy on the floor beneath me and press its green Run button. Voilà! The robot backs away from me for a second, then comes to a stop. In the parlance of these Legos, I turned its motors on, waited a second, then turned them off. That's the meaning of those three green blocks on my screen, snapped together into a program.

That's pretty cool, but hey, I've been programming for twenty years, so I immediately get more ambitious. I realize that I can control each of the motors independently: I can turn the left motor on while leaving the right motor off, so one wheel will spin while the other remains still. If I do that, my robot will turn. I could even alternate that motion so that my robot would slither along, turning first to one side, then to the other, like a serpent. And if I do it quickly enough, it will look like it's doing the jitterbug.

I look through all of the Command blocks and figure out which ones I need. Soon I have a neat little stack of blocks nestled

within a larger pair of red Stack Controller blocks, which tell my green blocks to repeat their actions forever. I've created a single jitterbug movement, but those red blocks will cause my robot to reproduce that motion ceaselessly.

Another download, and I've got a slithering, jitterbugging robot, weaving its way across my carpeting. This is cool, and easier than I thought it might be. I start to scavenge through the kit, looking for other things to attach to my robot. I come up with a touch sensor, looking like a 2×3 Lego, but with a small yellow nib on its front, a switch that I can depress with my finger.

I gently pry apart my robot and add the touch sensor, like some ultramodern hood ornament, using another of the connectors to wire it into the RCX, to the position labeled "1." There's a particular Stack Controller block called "repeat while," which looks at the touch sensor periodically, and if the sensor hasn't been depressed, will continue to run the robot through its dance. On the other hand, if the touch sensor has been depressed—meaning my robot has hit the wall or some other kind of obstruction—the robot will simply stop in its tracks. Now that I've added a sensor to the robot, I can use that information, feed it back into its program, and get it to change the behavior of its effectors.

My knowledge of Lego programming is far from perfect, so it takes a few tries, but soon enough, my critter careens back and forth across the floor, comes to a wall—and stops. Another successful experiment. Well, why stop there? I suppose I could use that little bit of sensor information to reverse the direction of the motors, or I could even run one motor for a bit so that the robot turns around . . .

That's when I realize that I'm in hip-deep and loving it. Something about this toy is bringing out the kid in me, bringing me back to the creative child who loved to play with Legos. But I know a lot more than I did as a child and am fresh from a few weeks studying Rodney Brooks's robots.

I begin to wonder how hard it might be to build a Lego version

of Allen, Brooks's first robot. All it has to do is run away from people. And that's not very hard. Hmm. A home-brew robot built out of Legos displaying the qualities of emergent intelligence? Now *that* would be cool. And I've got everything I need to make it happen.

THE (OTHER) HOTTEST TOY IN THE WORLD

Although it received just a tiny portion of the attention given the Furby, this toy I've been playing with, Lego's Mindstorms, was in very short supply during the Christmas season of 1998. At \$225 a set, it shouldn't have been flying off the shelves, but FAO Schwarz, the Tiffany's of toy retailers, couldn't keep it in stock. Lego, no stranger to runs on Christmas toys, had been caught completely unprepared, and doubled their production volume to meet demand. The retailers cried more, more.

In 1958 a tiny company which took its name from the Danish for "play well" introduced a revolutionary product, an interlocking system of building bricks that allowed for an infinity of possible combinations. Lego (*leg godt*) had been born. By 1966, about the time I first began to play with these plastic parts, nearly a billion bricks a year were being manufactured, packaged, and distributed all over the world.

Legos joined a long tradition of similar toys: Tinkertoys, Lincoln Logs (invented by a son of architect Frank Lloyd Wright), and for the electromechanically inclined, Erector sets, with motors, gears, and pulleys. Yet each of these lost some of their luster once the genius of the Lego system came into full prominence. Something about these interchangeable parts seemed so essential, so basic, and so adaptable that they quickly became the creative medium of choice for children around the world.

Although it had taken Lego's toy designers two decades to perfect their plastic bricks, the toys proved practically perfect, and very little changed in Lego-land for forty years. They added a few

basic components, such as the wheel, and extended the forms to include Lego figures, Lego families, and Lego astronauts, but it all remained variations on a theme, superfluous notes in an already perfect fugue. Children didn't need anything but the bricks themselves—preferably, a lot of them. (Given how long Legos last, there are likely many more Legos in the world today than people!)

In the late 1960s, Lego introduced Duplo, big blocks for children with tiny fingers, and scored a hit with the under-five set. Lego went after older children and young adolescents a few years later, in its Technic series, complex models with working motors that retained their snap-together ease of construction, but offered activity in equal proportion to imagination. Each of these had a fair amount of success, but nothing to compare with the original; the basic bricks continued to sell in ever-increasing quantities.

By the time the high-tech revolution was in full swing, as computers began to show up at home and in schools, Lego, working with a group of researchers at MIT, introduced Technic Computer Control, a system that allowed Technic robots to be controlled via a computer. Distributed only to schools in Denmark and England, the product was more of a test than a toy, setting the stage for some pivotal mass-market product introductions in the 1990s, beginning with the Technic Control Center, a kit of programmable robots for the Technic series of toys. These early Lego efforts got some attention in the press and had a few buyers in the educational markets, but never really made it big. The programming, still a bit cumbersome, presented a barrier to all but the most inventive and intelligent children.

Lego, learning from its successes (and its failures), continued to refine its designs for robotic toys, with plenty of help from MIT. By 1997, the designers had gotten it just about perfect, and in the middle of 1998, Lego introduced the Mindstorms Robotics Invention System.

Lego never knew what hit them. Somehow both the product

design and the zeitgeist conspired to create a buzz around this newest addition to their product family, and they optimistically projected sales of 40,000 units over the Christmas season—at a hefty \$225 retail price. But as September melted into October, Lego found itself swamped with orders. Toy retailers were restocking their supplies over and over. Every time the sets shipped, they immediately sold out. So Lego doubled their projections again—and still fell short. In all, over 100,000 Mindstorms sets sold before Christmas 1998. They had another hit on their hands.

As buyers mailed in their warranty cards and Lego's marketing department carefully studied the age and gender distribution of their customer base, they found something utterly unexpected. Half of the Mindstorms sets had been purchased by adults—for their own use. This was unprecedented in Lego-land: after all, Lego makes toys for children. Mindstorms had touched the child in a multitude of adults.

With its 727 pieces, including two motors and a few sensors, the Mindstorms kit differed from earlier Lego products in one significant way: it included a device known as the RCX, the Robot Control and eXecution unit, the brains of the beast. The top of the RCX has an LCD screen that displays the status of the unit, as well as pads where up to three motors and three sensors can be simultaneously attached. The motors can be turned on and off by the RCX—literally, it functions as a power switch—while the sensors can have their values read in and interpreted by a user-created program running in the RCX.

As with the Furby, another enterprising engineer has taken a look under the hood of the unit and documented his findings on the RCX Internals website. Like the Furby, the RCX contains a single printed circuit board with a variety of capacitors and resistors, the building blocks of most electric systems, embedded around a single large chip.

That chip, a microcomputer manufactured by Japanese electronics giant Hitachi, contains the programming used by the RCX

to interpret commands sent from the computer: to turn on a motor or read a sensor or pause a moment. The RCX translates these commands into computer instructions required for the task. This means that the RCX can be given a series of very simple orders spelled out in a stack of virtual Lego bricks and then translate these into complex actions. It also means that other engineers far outside the influence of Lego can write software for the RCX using a variety of tools, not just those supplied with Mindstorms. And many have.

Almost immediately after the release of Mindstorms, a whole host of websites sprang up designed for the adult owners of the toy. Many of these sites took a sophisticated approach to the playful possibilities offered, demonstrating a plethora of different Lego robots that could be built out of the kit, along with their control programs. One owner designed a Lego sorting machine that could winnow through different-sized Lego bricks; another built a remote-control robotic arm, and yet another constructed a Lego race car. Some folks went even further.

David Baum, an engineer at Motorola, created a new programming language for the RCX loosely based upon the C programming language favored by the vast majority of software engineers. (Developed in 1974 at Bell Labs, today nearly all computer programs are written in C or C++, its younger brother.) Baum called his creation NQC, which stands for "Not Quite C," and it opened the world of Mindstorms to the professional programmer who felt constrained by the comparatively easy-to-use programming tools offered by Lego. Programmers, like race car drivers, often try to get as close to the metal as possible, equating power and performance with access to the internal guts of a computer.

This was no small job. As a corporate outsider, Baum had to learn how the RCX worked without the benefit of the technical information which would have made the job only moderately difficult. Instead, he had to play with the RCX for many hours,

testing its capabilities, treating it like a black box and watching it closely as he drove it through its paces. From these observations he was able to duplicate the function of the software tools supplied by Lego, wrapped within a software development environment (NQC) that professional engineers would find more comfortable.

Why would anyone spend so much time studying a toy? Not for the money. Baum gives away NQC freely on his website, without even asking for so much as a thank-you. In the era of the Internet start-up and the IPO, with seventy thousand potential customers out there, this may seem a bit curious, but some things are done for love, and Baum is clearly in love with his Mindstorms. First and foremost, he's a robot enthusiast, and he wants to share his passion with the world. There isn't a whole lot you can do in NQC that you can't do with Lego's tools, but programmers tend to think of their favorite programming languages in much the same way you might regard a worn-in pair of shoes. The fit is comfortable, reliable, and friendly, and that means a lot when a programmer gets down to the mental gymnastics of writing software.

Baum is not alone. Other programmers have created RCX versions of FORTH, an old and venerable language with an intense community of devotees; PERL, a language often used to process web-based forms; and Java, the current hot computer language. If you know a computer language, chances are you can find a version to run on your RCX. And if you don't, Lego has created a programming environment even a child can use. In fact, it was meant for children, designed by a researcher who fully understands the importance of play.

A KINDERGARTEN FOR PH.D.S

Throughout the middle of the twentieth century, Jean Piaget, while developing the principles of constructivism—the idea

that children learn about the world through discovery and experimentation—played host to a wide range of students and researchers. Through his mentoring, Piaget extended the influence of his ideas far beyond his Geneva home, and through one particular postulant became a fundamental influence in artificial intelligence research.

Seymour Papert began his studies under Piaget in the late 1950s, toward the end of the elder researcher's career. The interaction proved to be explosive for Papert, leading to a series of ideas that would fundamentally influence education. But rather than becoming an educator himself, Papert joined colleague and friend Marvin Minsky to found the MIT Artificial Intelligence Laboratory. Papert believed that Piaget's research would have broad applicability in the field, a theory AI researcher Rodney Brooks would put into practice in the 1980s when he built robots that grew into intelligent behavior.

In the mid-1960s, working with researchers at Bolt, Beranek, and Newman, a Cambridge think tank simultaneously working on the basic foundations of the Internet, Papert created a computer programming language that encapsulated the constructivist ideas he had learned in Geneva. The result, LOGO, was the first computer language designed to be taught to and used by children.

LOGO, originally envisioned as an offshoot of LISP, the programming language of choice for AI researchers, provided the child with a basic set of operations, such as adding two numbers and printing the result on the display, but LOGO also allowed the child to experiment with these operations, putting them together into novel combinations, which would then become parts of more sophisticated programs. Children, according to Piaget, build an understanding of the world from basic concepts that become the basis for more advanced ideas. LOGO worked along precisely the same lines: once a child perfected a set of operations through experimentation, these theories could be put into practice. With

LOGO, children could enlarge their understanding of the computer through their own idiosyncratic investigations, and, like a Lego tower, place newer elements upon older principles until something truly novel emerged.

Papert tested his creation with students in Brookline, an affluent community just a few miles up the Charles River from MIT, and realized that children learn more quickly when they have real-world objects to play with as they are learning. To this end, Papert developed the Turtle, a small, squat robotic creature that rolled about the floor and could be controlled with LOGO programs. This physical interface device took the abstract language of the computer and translated it into the robot's physical movements, a powerful amplifier of LOGO's capabilities. When children saw the results of their experiments reflected in the Turtle, they learned faster, because the Turtle acted as the embodiment of their thinking, a reflection of their growing understanding.

The little Turtle was both expensive and delicate, and as the 1970s progressed, the Turtle became virtual, a critter on a computer monitor under LOGO's control. Although no longer embodied, the on-screen Turtle became a key element in the LOGO environment as the personal computer revolution exploded in the late 1970s, creating a base for LOGO to move from the classroom and into the home. Two home computers became the platform of choice for home versions of LOGO. One of them, the TI 99/4A, developed by Texas Instruments, creators of the Speak and Spell, carried a \$200 price tag—well within the reach of most middle-class families. The LOGO cartridge for the TI 99/4A opened the world of computer programming to a generation. Many of America's best programmers got their start playing with LOGO on the TI 99/4A.

The more successful platform for LOGO was the incredibly influential Apple II. Designed by Steve Wozniak, the wizard of Silicon Valley and cofounder (with Steve Jobs) of Apple Com-

puter, the Apple II found a place in millions of American homes, and because of Apple's aggressive marketing to educational institutions, in many schools. Millions of schoolchildren got some exposure to LOGO through the Apple II, using Turtle Graphics to program their own artistic and scientific creations, learning by playing.

Papert published the results of his revolutionary work in 1980, in a book entitled *Mindstorms: Children, Computers, and Powerful Ideas*. Yes, the Lego kit is named in honor of his pioneering vision: children can master logical thinking and complex concepts through play and exploration. Papert's book influenced both educators and computer scientists, who came to see the computer as a vehicle for learning, rather than just an instructional engine. Before Papert, computers were frequently seen as drill instructors, pushing students through rote problems; after *Mindstorms*, the computer became a sandbox of sorts, flexible enough to adapt to the child's evolving imagination of the world.

Just as *Mindstorms* reached bookstores, the Massachusetts Institute of Technology, Papert's home base, began an ambitious project to bring itself into a leadership role in the twenty-first century. In 1980, Jerome Wiesner, former science adviser to President Kennedy, was nearing the end of his term as president of MIT. Although MIT's reputation had been made in the hard sciences, Wiesner recognized that its future belonged to visionaries who could translate these technologies into useful applications. This idea put him at odds with an older generation of MIT professors who disdained anything but the most rational and scientific avenues of research. But Wiesner found a kindred spirit, someone to help him realize his vision, in a rising star at the Center for Advanced Visual Studies—the closest thing MIT had to a graduate program in the arts.

Long before he became the poster boy for the digerati, Nicholas Negroponte looked into the future and decided that it would be digital and interactive. Although the Center for Ad-

vanced Visual Studies had been ignored by most of MIT's faculty as too fluffy, Negroponte leveraged the substantial technical resources of the Institute to create a hugely influential work of interactive media. Known as the Project ArchMach (Architecture Machine), the device consisted of a high-backed office chair placed before a large projection screen. Mounted on the armrests of the chair, a number of input devices—such as a keyboard and mouse—allowed users to manipulate a virtual office represented on the display. Negroponte worked hard to create an impressively realistic representation of a real office, with file cabinets that could be opened, containing files that could be placed onto a desktop and manipulated. Designed to be an idealized electronic work environment, the ArchMach pushed computer graphics—just at their own beginnings—to the limits of the possible, providing one of the first examples of virtual reality nearly a decade before VR pioneer Jaron Lanier coined the term.

In Negroponte, Wiesner had found a scientist who understood both technology and its application. They began to plan MIT's entrance into the softer world of applied design, an effort that became known as the Media Lab. Now world-famous for its pioneering research, the Media Lab has fulfilled Wiesner's ambition: a meeting of science and art in an environment where each informs the other. Of course, Negroponte couldn't create a world-class institution by himself. He needed a lot of help, so he quickly invited Seymour Papert to set up shop under the Media Lab's roof.

The Epistemology and Learning Group at the Media Lab, founded by Papert in 1981, clearly gives a nod to Piaget's concept of genetic epistemology, the idea that experience in the world creates the foundation of learning. It also reflects Papert's extensive experience in using computers as tools for discovery and exploration. Given his considerable reputation, the group quickly became a magnet for graduate students wishing to study under the godfather of educational computing.

As Negroponte set up the Media Lab on the East Coast, a high-technology industry began to flourish on the West Coast. *Business Week* sent a young reporter named Mitchel Resnick to California's Silicon Valley, where companies like Apple, Intel, and Hewlett-Packard dominated the emerging high-technology industry. A thousand garage start-ups flourished across the cities of the Valley, and Resnick covered all of it, taking the technospeak of the Valley's nerd-kings and translating it into language a lay readership could understand. He saw himself as a bit of an educator, out on the front lines, bringing the business practices of the Information Age to a wider public, acting as a bridge between the well-established world of atoms and the nascent world of bits.

As Resnick spent time in this technological playground, he grew more and more excited about the possibilities latent in the new toys being created by the ever-increasing waves of engineering talent and entrepreneurial spirit flooding the region. In particular, Resnick was fascinated by how computers could be used to help people understand complex systems. Could they become a platform for explanation and exploration? As a reporter charged with explaining the complex, Resnick found himself irresistibly drawn to this aspect of computing, and after five years on the beat, he left *Business Week* to enroll as a graduate student at MIT, entering its renowned computer science program.

Early on, Resnick became friends with another graduate student, Steve Ocko, who shared his interest in educational computing, and a few months later, the two took a course taught by Seymour Papert, who filled their imaginations with the possibilities explored in the recently published *Mindstorms*. In another seminar, led by researcher Sherry Turkle (soon to go on to publish *The Second Self*, exploring the relationship between children and computers), they explored the developmental psychology of children interacting with computers. It added fuel to the fire, and soon the pair was bursting with ideas, dreaming up schemes that would harness the power of the computer to playful learning.

The duo had complementary interests. Ocko preferred the physical world of objects, while Resnick felt most at home in the virtual world of software. When they cast about to develop their ideas into a toy, Legos, both very physical and yet virtually unlimited in their possibilities, seemed a natural foundation. A computerized Lego set could be used to endow the real-world experience of design with interactive depth, turning a static stack of bricks into a responsive object. Under Papert's guidance, the two began their work. Then something very fortuitous happened: Lego came for a visit.

In the autumn of 1984, the designers at Lego saw Papert interviewed on television and realized that Papert's ideas were remarkably similar to their own. Both stressed the importance of creative play as a fundamental learning experience for children. Lego had no agenda for the meeting; they just wanted to have a chat with the dean of educational computing. But when Papert informed Resnick and Ocko that the toy maker would be paying him a visit, they snapped into high gear, readying their prototype computer-controlled Legos for a demonstration.

Exceptionally successful at manufacturing toys without any active components, Lego had begun to entertain the possibility of extending their designs into more technological areas, not as an end in itself, but as an enhancement of the creative potential already present in the bricks. They had no firm plans and wanted to speak to Papert as part of a larger effort to fully grasp the capabilities of interactive aids to playful design. Lego certainly hadn't expected to see their future fully realized, but they were in for quite a surprise.

During the meeting, Resnick and Ocko presented a Lego system with an integrated system of motors, controlled by an Apple II running LOGO, Papert's child-friendly programming environment. This demonstration fairly blew Lego designers away, bringing the best of both worlds together in a way that diminished

neither. In fact, these active bricks took the design possibilities to a new level. With strong encouragement from Lego, the two continued their work, refining their designs and adding mechanical components and software. In the summer of 1985, they dropped them in front of a group of children from a nearby school attending a two-week computer camp at the Media Lab.

The kids went nuts. They built a miniature amusement park with a variety of rides, all computer controlled, along with robots, houses with automatic doors, and a whole host of other inventive forms. Along the way, these children were learning about mechanics, physics, and programming, but they didn't even notice this; the learning was a means to an end, and play was the order of the day. When at the end of the camp, Resnick announced that these toys would follow them into the classroom (where Resnick would continue his research), the kids reacted with a mixture of disbelief and horror. This *couldn't* be schoolwork, they argued. It was fun. What does fun have to do with learning? This is a toy, it's fun to play with. Not school, nothing like it.

That's when Resnick understood how well he'd done his job. He'd wanted to focus on how children learn when they design things, believing design to be the best opportunity for a learning experience. Now he had proof positive that children *could* learn complex ideas quickly, without tears or pain, rote repetition or memorization, a transparent process of play leading into a richer understanding of the world. This research gave him the inspiration for his thesis, and in 1992, as he got his Ph.D., he joined the faculty of the Media Lab as a researcher in the "Lego Lab," in Papert's Epistemology and Learning Group.

Lego used the Media Lab's designs in a number of products. Meanwhile, Resnick and his team of graduate students kept plowing ahead. It took about four years to bring the first computer-controlled Technics kits to market. By 1988, Resnick was convinced they had further to go. These toys still required

that the motors be physically attached to the computer—fine if you're making a static structure, such as a house, but very confining if you want to construct a robot or other autonomous object. If the Lego bricks could contain their own computing power, they could act independently—programmed via a computer and then sent into the world, untethered.

The programmable brick was the answer to this problem. Today the Media Lab focuses on ubiquitous computing, envisioning a world where computers are embedded everywhere in the environment, as they already are in the typical kitchen. Resnick and his team adapted this idea to their Legos long before the rest of the Media Lab had caught onto the idea of ubiquitous computing, creating a self-contained block with its own computer, sensor inputs, power outputs (to drive motors), infrared communications, and power source. The brick didn't need to be physically attached to a computer to communicate with one, so the computer could still be used as a programming environment. Once a program had been created, it could be downloaded to the brick, which would then run the program.

Resnick's team built a prototype and sent it out into the field—the museums, classrooms, and after-school centers eager for technological gizmos to spark the creative imaginations of children. Soon they found themselves surrounded by all sorts of autonomous toys: robots of different shapes, sizes and capabilities, all based upon the same brick. Even better, the children could use multiple bricks for a project. The infrared link that ran between brick and computer could also be used to pass messages—little bits of information—between bricks, so that the robots could act in concert, invisibly whispering their activities to one another, creating very complex behaviors from simple components.

That brick, christened the RCX, became the central element of Lego's Mindstorms. Although it took nearly a decade for Mindstorms to make its way from the Media Lab to the shelves of toy

stores, Resnick and his team are gratified that their research has proven to be popular. "We believe there's a hunger for these things," he says, "but that's a hard sell, because many people believe kids won't respond to these kinds of toys. It's satisfying to know that there's a whole community growing up around them."

The success of Mindstorms reveals the genius of Resnick's design. The kit lives in a sweet spot between soldering together electrical components (too low level for any but the most hardcore hobbyist) and an inflexibly programmed toy that would soon bore most children. Mindstorms strides a middle path, giving its users just enough prepackaged technology to get them up and running without hampering their creativity. The child focuses on the creative endeavor while the RCX sweats the details. It's a potent combination.

Lego has shown their gratitude to the Media Lab by endowing the Lego Chair, now held by Resnick, and funding a \$5 million "Lego Lab." Resnick's offices at the Media Lab are—to put it mildly—unconventional. A cavernous space with offices along its outer walls, the center of the lab features a pit of computers, toys, and a wall of Legos, neatly stacked into boxes of different sizes and colors. Graduate researchers sit in front of computer workstations, eagerly coding the next insanely great tool for educational computing or observing children as they play with toys. The whole space is decorated in bright primary colors, looking very much like a kindergarten for Ph.D.s.

This is no accident. Resnick believes that Friedrich Froebel, who created the first kindergarten in early nineteenth-century Germany, discovered something we tend to suppress as we grow into adulthood. Kindertartens present children with the opportunity to learn by playful exploration, design, and interaction. Historically, the enriched environment of kindergarten gets left behind as children progress into a more sophisticated understanding of the world, and the interactive possibilities of play are

discarded in favor of books and other mediated learning materials. But children don't change as they grow older—they still acquire their knowledge in the same way. Resnick has become the advocate of lifelong kindergarten, where design, interactivity, and personal connection to the learning process become the integral features of education. Rather than reading about physics or math, Resnick wants children (and adults) to participate in an exploration that will feel much like play but will result in the acquisition of a broader base of knowledge—learning by doing.

If this seems obvious—and it is, to many parents—it can only be emphasized that we're not accustomed to educating our children according to these principles—at least, not once they've gone beyond kindergarten. Resnick is calling for a change in our educational mind-set. Through technologies like Mindstorms and the World Wide Web, children can become their own educators. If children seem reluctant to learn their classroom lessons, perhaps they'd be more apt to learn by playing. An educational environment designed to engage them through play could well unleash a creative explosion in childhood learning.

Resnick hasn't finished his work with Legos. Mindstorms, though selling well, represents just a midpoint in his inventive efforts. They're too big and expensive for a child to experiment with more than one at a time. If they could be shrunk down to the size of the standard Lego brick (the RCX is a monster compared with your average Lego) and manufactured even more cheaply, then children could use ten or twenty of them in a single project, creating truly novel designs from an array of active building components. Resnick has an obsession with complex systems, in which simple components work together to produce complex behaviors, much as Rodney Brooks's robots do. He wants to explore the educational possibilities of a whole "flock" of bricks working together on a single task.

Resnick already has his group working on another toy, the Cricket, a prototype for the next generation of Legos. Not very

much bigger than the nine-volt battery used to power it, the Cricket has even greater capabilities than the RCX, but is one-eighth the size. And these Crickets are designed to chirp, able to communicate efficiently with one another, using infrared light to transmit complex messages that can be used to coordinate the activity of all Crickets participating in a given task. Using the Cricket, a child could create a flock of Lego robots, each communicating with its neighbors to work on a common task, much as ants or bees do in their colonies and hives. With these kinds of toys, Resnick speculates, we'll be able to help children learn about the complex systems that make up real life—things like traffic jams and stock markets and other phenomena that defy simple description—the kinds of experiences children will need to make their way in the twenty-first century.

We know that computers get smaller, faster, and cheaper with every passing day. The Cricket is probably just another midpoint in an increasingly active, increasingly tiny world of intelligent components. To understand just how small the Cricket will become in the next decade, we need to step back forty years and hear a few words from a man who said the most outrageous things—most of which happened to be true.