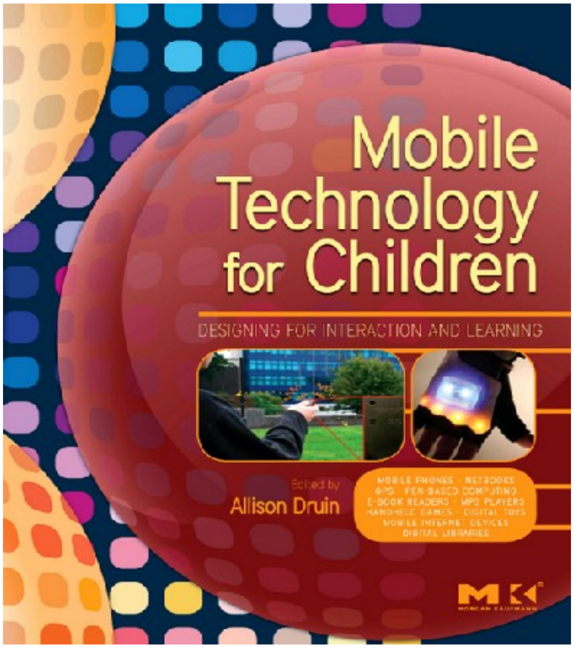

From Christopher Hoadley, Social Impacts of Mobile Technologies for Children: Keystone or Invasive Species? In: Allison Druin, editor, Mobile Technology for Children. Boston: Morgan Kaufmann, 2009, pp. 63-82.
ISBN:978-0-12-374900-0

CHAPTER 4

Social Impacts of Mobile Technologies for Children:

Keystone or Invasive Species?

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This chapter describes the role of mobile technologies in children's technological ecologies. In particular, based on work in developing nations, I discuss ways in which technologies can be potentially disruptive to cultural, educational, or technological systems that children inhabit. A few cautionary tales illustrate how well-intentioned designs that function appropriately in some contexts are actually harmful or disruptive in others. Although design often considers the special needs of children or other audiences, it should equally consider context and interdependencies, especially working in areas where local sociotechnical ecosystems have had less contact with and adaptation to the technological "species" that are common elsewhere.

THE SPREAD OF TECHNOLOGIES IN RURAL SOUTH ASIA: TWO STORIES

The Pentium in the village

In 2004, I began going to South Asia to learn about ways in which technologies were being used in education in the Himalayan region. I visited a number of groups doing various forms of education, ranging from traditional school-based programs and community-based activities to public relations campaigns (such as public service announcements about health or environmental issues). One initiative in particular caught my attention: The state of Uttarakhand in India had undertaken to put computers in every school in the state. Accompanied by a prominent local curriculum developer and educator, I went out to see what this program looked like in action.

Mobile Technology for Children: Designing for Interaction and Learning

ISBN: 978-0-12-374900-0

The educational system in India, as in many other countries, is a patchwork of government-run and privately run schools. (To avoid confusion, I'll call the publicly run schools *government schools* and the independent, commercially run schools *private schools*.) As in the United States, there is also a patchwork of constituencies and jurisdictions that set policy for these schools. Typically, states within India have the ultimate responsibility for running government schools, although that responsibility might be delegated to agencies or even private groups within the state. In many cases government schools are the only schools in very rural areas, and they might consist of a simple building without heat, windows, or electricity.

Though schools are relatively plentiful, there are deterrents to attending school. Especially in the higher grades, students might have to walk hours to and from the school, there might not be practical toilet facilities (a real issue for menstruating girls), and the practicalities of life in a subsistence agricultural economy often mean that children do not attend school if they are needed at home to fetch water or gather fodder (Pande, 2001).

In general, the school system is geared toward a final goal of "school-leaving exams," either state- or nationally driven final exams administered in the 10th grade, or "10th standard," which determine whether a student can continue on for further education. Though the top universities in India rank among the best in the world, the leaving exams represent an enormous funnel through which only the tiniest fraction of students will be admitted to a top college. Typically, as in other countries, social class, economics, and geography play a large role in how well students fare in these exams.

The state of Uttarakhand is a new state within India, formed less than a decade ago. Recognizing the distinct needs of the population in the hilly or mountainous areas, it was carved out of the plains-heavy state of Uttar Pradesh. As such, it had a rare opportunity to define for itself the way things would be done in the state. The IT revolution is no secret, nor is its role in driving the urban economy of India. Computer facilities are often used as a selling point for elite private schools (see Figure 4.1). The state used the opportunity to provision every school in the state with a handful of desktop computers, hoping to give students who might otherwise be disadvantaged a leg up in their schooling. Each school received computers, a printer, and, if necessary, a generator to power the machines. Teachers were provided with a week or so of training, supported in part by Microsoft. I'm quite familiar with the efforts in the United States to bring computers into all schools, equitably, through the 1990s, and to me, this state effort seemed like a wonderful attempt to bridge the digital divide.

To make a long story short, in the schools I visited the initiative ranged from somewhat helpful to truly harmful. On a positive note, one primary school I visited had a group of children taking turns to use an educational CD-ROM on environmental issues. The program (in Hindi) was produced and distributed freely by a prominent Indian nonprofit. For these students, Hindi is their native language, which is fortunate, given the large numbers of languages spoken in India (over 200, with more than 20 official or recognized languages across the states). The teacher was quite progressive in dividing the class so that one group could use the computer while the others worked on other assignments, in contrast to the whole-class formats typically employed. Still, a dozen children were viewing a single screen and watching someone else play a game.

FIGURE 4.1
Sign advertising an elite boarding school in a well-known tourist area. The sign touts "Personal computer with On-Line Internet service, Television with Cable Connection," and "Mobile Facilities" in addition to "Wall to wall carpet," "Luxuries (sic) food on demand," and "Personal Attendant."

We saw a more depressing, and more typical, situation in a lower secondary school. This school was perhaps 30 minutes from the road by footpath and was locally considered to be a good school. Because the village did not have power, barrels of fuel to run the state-provided generator had to be carried in on someone's back. Although the computers and initial training were provided by the state, the school had to bear considerable costs as well. The school's computers and generator had cost about 120,000 rupees, or approximately US$2500. But the school had to front approximately half that amount again, approximately US$1200, for renovations to the building to install power outlets, for furniture to put the computers on, and for locks or other security-related renovations. It is vital to remember how difficult it is even to provide space for a computer room where space is at a premium (see Figure 4.2). In many countries these costs would seem small, but it is important to remember that in this context a teacher's annual salary might be as low as 80,000 rupees. We heard stories of other schools keeping the computers locked up and unused except when dignitaries came to visit, because no provision had been made for repairs or upgrades; even if there had been a budget, getting the computers somewhere they could be repaired would be a huge burden.

In this school, the computers were used with a rigid drill-and-practice IT curriculum that emphasized how to use Microsoft Office. The teachers would manipulate the software, demonstrating how to format a paragraph, while the students—all 30 or 40 of them—duly took notes. No projector was involved; the students sat around on the floor watching a single CRT monitor. Students had IT textbooks and paper-and-pencil tests about how to operate the software. In general, the computers had to be used after regular school hours because the noise of the generator was too disruptive to the other students. There was no Internet access.

a b c

FIGURE 4.2 Classroom facilities in some rural South Asian schools. (a) A lower secondary school building. (b) One of the classrooms in the lower secondary school. There are approximately 45 children in an approximately 3 × 4-meter (9 × 13-foot) room. (c) A new computer classroom in an upper secondary school in Uttarakhand.

The community actively resented the presence of the computers. According to school staff, when the school asked the parents to contribute 10 rupees per student per year for fuel, many flatly refused. The money itself was not the issue; all the parents were already spending more than 10 rupees on uniforms and books. Parents heavily valued education, as evidenced by sending their children to school at all. But, like so much of the schooling, the computers were geared toward success in urban environments, not toward success in the rural communities.

Educational needs in the villages vary significantly from urban skills. Many of the villages in the region face terrible social ills related to urbanization; men leave to find jobs, and they might send money back or they might abandon their families to begin anew, even remarrying, leaving many villages full of women, children, and the elderly to conduct farming. Monetary poverty is typical in the villages, but unlike in the large cities, money isn't strictly necessary to live well when conducting agriculture in the traditional communities. The local culture is besieged by population drain from urbanization, and although we met with youth groups trying to invent ways to make a living and stay in their home places and cultures, many youth feel they have no choice but to leave their communities if they can. Against this backdrop, the idea of preparing children with IT skills, recognizing that they face discrimination and numerous other disadvantages that would more strongly prevent them from "striking it rich" in the IT industry, seemed ludicrous to these parents. And at least one of the teachers we talked to, who was himself from an urban area but had been posted to the village by government assignment, spoke with contempt about the ignorant parents and their provincial concerns. He was completely oblivious of the values of the community, and it's pretty easy to assume that he would not have taught the children in a way that they might apply IT skills in their rural culture. In general, the computers were helping to rip kids from their families, their culture, and their place.

The mobile phone in the village

Let's consider a contrasting example of a technology that was warmly welcomed by the local population: mobile phones. When I began visiting Uttarakhand in

2004, mobile phones were basically unheard of; the national telecom, formerly a monopoly, had some towers up in the same district, but they were a new arrival. The same educator who took us around was an early adopter and would try getting mobile signals on various hilltops, but coverage was basically limited to the town itself. Similarly, in Nepal the national telecom rationed services and published notices in the newspaper, citing days on which coveted mobile Subscriber Identification Module (SIM) cards would be sold at banks at the stupendous price of more than 10,000 Nepali rupees (roughly US$150).

Within four years, not only had mobile coverage improved vastly, there was also an array of carriers from which to choose. Previously, one could see the effects of globalization via the ubiquitous logos of soda and snack companies (Lay's, Kit Kat, Pepsi, etc.), even in villages without power or refrigeration. Often stores would have their entire buildings painted as advertisements for one of these snack companies. Within those four short years, mobile phone ads had replaced many of the cola ads and had become generally more prevalent than snack ads (Figure 4.3). Prepaid mobile phone recharge cards became available at every corner store (Figure 4.4).

It should be noted that these handsets are comparable in price to those in more industrialized countries, ranging from about US$40 up to several hundred dollars. With a nominal gross domestic product (GDP) of $2600 per capita and 25% of the population below the poverty line (*CIA Factbook*, 2008), in this area a mobile phone represents a significant personal investment. Yet the number of mobile phones is exploding. These phones are used by both literate and

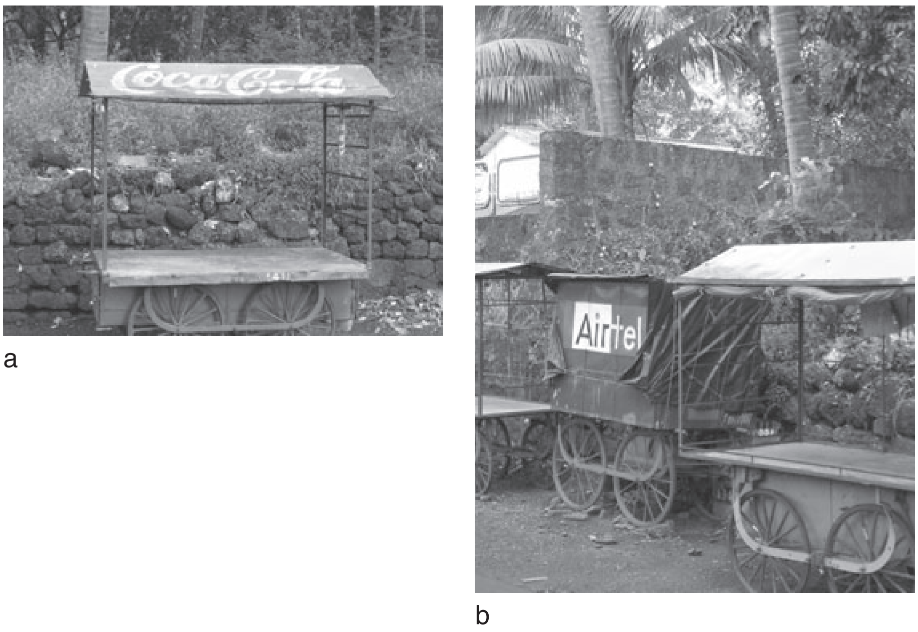

FIGURE 4.3 Advertising on adjacent vendors' carts. (a) A soda company ad. (b) A mobile company ad.

FIGURE 4.4
A local public call office, or PCO, which now also sells mobile devices and recharge cards. In more rural areas, PCOs also frequently serve as convenience stores, selling candy, chips, soft drinks, tobacco, and betel (paan). These paan shops often do not have electricity from the grid.

illiterate people, by middle-class and working-class families, and even by people who don't own one, who access them through local entrepreneurs who sell time on their own mobile phones in remote locations (Corbett, 2008). Mobile phones haven't got quite the same penetration into villages far away from the road, but in general people seem friendly toward the technology; for instance, from 2002 to 2007, mobile subscriptions in India leapt from 13 million to 234 million, roughly enough for one phone to every four to five people in the country (International Telecommunications Union, 2008). We might reasonably think that mobile phones are simply poorly suited to rural villages because of the huge amounts of capital required to set up the towers and the monetary infrastructure needed to allow people to pay for these phones as they use them. Clearly, advertising is helping this process along, but in a nation where public call offices, or PCOs (payphones), are common along every road, we might ask, why are these telephone devices being adopted quickly when desktop computers are not? Moreover, is it a good thing that some technologies are adopted while others are rejected? What criteria might we establish for positive vs. negative examples of dissemination? An analogy could help answer these questions.

Technology as a species in an ecosystem: An analogy

When I lived in Northern California, I used to take long walks in the Tilden Regional Park, a beautiful wooded landscape scented by eucalyptus and dotted with various plants that often sported signs labeling their genus and species. It seemed like a rare glimpse at California in its natural state.

Not long after I moved there, a dangerous fire consumed much of the hill region in which the park was situated. I attended a talk by a geographer about the causes of the fire and was stunned to learn that the true natural state of that area was grasslands. The eucalyptus trees had been brought in from Australia and sold to lumber speculators, who quickly discovered that although the trees did grow quickly, they were useless for lumber—so the tree-covered land was sold off or donated and eventually became parkland and residential areas. Furthermore, early naturalists proudly brought as many nonnative species as possible to be planted in the parks. Through efforts such as these, an area that might typically be open grazing fields was transformed into a forest, increasing the biomass (and the potential destructiveness of fires) by an order of magnitude. Native species were displaced by interlopers, and the ubiquitous eucalyptus was enough of a problem that the state eventually tried to remove it from a park on a nearby island in San Francisco Bay. And those signs noting genus and species? They were attached to primarily nonnative species proudly imported by people involved in what was called the acclimatization movement.

I've thought often about those early naturalists. They had the best interests of nature at heart, with great love for the broad diversity of plants and animals. They believed in the "more is better" paradigm where it comes to nature. But what separates their actions from those of current environmentalists is today's understanding that the flourishing of a species is not, in itself, a good thing; each organism lives in an intricate web of relationships shaped by its environment, and disrupting this web has real costs. For example, we might typically classify corn as a productive crop and kudzu as a nuisance plant, but each can be a key supporter of a healthy local ecology or an invasive species that destroys the delicate balance of a particular ecosystem.

When technologists, policy makers, teachers, and parents consider bringing technology into the lives of children, they often behave like those early naturalists, assuming that something shown to be of benefit in one situation will be inherently useful in another. With the very best motives, we try to take things that have worked well in previous situations and introduce them to "help" in new contexts. We might also carry technologies with us from context to context, without much thought as to the role they might play in the new context (bringing the work laptop home comes to mind). And, like species, technologies have a complex set of relationships with their "ecosystem." They consume certain kinds of resources and provide others. They change the behavior of users as well as their relationships to other organisms and to other tools in the environment. And, like the nonnative flora or fauna, the ripple effects are often unpredictable and at least as large as the first-order effects.

I'm old enough to remember the worried newspaper articles about how microwave ovens appeared to be single-handedly destroying the family ritual known as dinnertime in the United States. First-order effects such as greater autonomy and more free time were predicted, since microwave ovens could cook (certain things) more quickly. Microwave cookbooks blithely described how to make a roast or a cake in the microwave oven, tasks for which the device is poorly suited. But few people would have predicted that an entire industry of microwave-ready meals would spring up, further pushing diets toward unhealthy processed foods; that in many workplaces cafeterias would be replaced by break rooms where people would quickly reheat their lunches and take them (anti-socially) to their desks; and yes, many families lost the nightly ritual of checking in with one another over a shared meal. I've also been in workplaces where the break-room microwave proved better than the water cooler for ensuring a bit of chit-chat with colleagues, in a way that running out for a bite at a fast-food restaurant wouldn't.

I don't intend to be a naysayer or a Luddite; things change, often for the better, and I'm quite happy to have a microwave oven at my disposal. I myself have great hopes for the possibility of technology to improve the lives of adults and especially children, who can grow up as digital natives, fluent at using tools to achieve their goals and to live their lives as fully as possible. But in the remainder of this chapter, I hope to explore ways in which technologies being introduced into new settings demand that we should think holistically and relationally. It is up to us to ensure that our technologies don't take on the role of "invasive species," destroying the very settings we hope to improve.

As George Box famously said, "All models are wrong; some models are useful." Prior work has shown the value of other ecological metaphors in the use of technology (Bates, 1989; Pirolli, 1993). Let's explore where this ecological metaphor breaks down and where it might yield insight.

What counts as an "invasive species" of technology?

One key strength of taking technologies as species and contexts of use as ecosystems is that we can differentiate between evolutionary change and destructive change. Ecologists use the notion of *succession* where technologists might use the word *progress*; in some cases a shift in the species in an ecosystem is a relatively predictable move toward an ultimate equilibrium. Just as a meadow is replaced by a forest (until the forest burns down and the cycle begins again), we might expect dial telephones to be replaced by touch-tone phones and slower microprocessors to be replaced by faster ones. Though the tree species that replace the grasses might be expanding their range into the meadow, they are not "invaders" per se, because they evolved as a part of a natural progression along with the other plants and animals of the region. Similarly, I wouldn't treat a nicer car coming into my garage and displacing my old junker as an invasive species; typically, newer, nicer cars replace older ones as resources permit.

Which brings us to the question, what is a native species in technological terms? Obviously, the geographic origin of a technology isn't quite the deciding factor; my 110-volt hair dryer might have been manufactured in China, but it was never designed to thrive there (where plugs and power might be incompatible), so site of manufacture isn't good enough for our discussion. Similarly, a winter coat might have been designed in Milan and manufactured in Malaysia, but it's too warm for either place, since it was intended for sale in Montréal. The coat would never thrive in the place where it was designed, so its design location isn't the native habitat.

Is the native habitat the place *for* which something was designed? Even that might not always work. I'm reminded of a story I was told of a government program designed to limit the use of wood for cooking fuel in India (Pande, personal communication, 2006). A Western nonprofit designed solar cooker boxes, and thousands were purchased and distributed by the government (Figure 4.5). The locals were happy with their cookers, and the nonprofit and government were happy with the distribution.

However, not long afterward, people were using the foil-covered cooking box portion of the solar cooker for storing clothes. Why not use it for cooking? Well, for one, many working people needed to take lunch with them, and the housewives had to make breakfast and lunch at or before dawn. Hence, the solar cookers weren't being used because they didn't fit within the web of relationships that determined how and when families cooked and ate. One could argue that they *were* used, but just not for their intended purpose; however, it would appear to be a huge waste to manufacture solar cookers when simple storage boxes could have been manufactured much more cheaply. Inefficient or unsustainable resource use is one hallmark of an invasive species.

Thus, what seems to distinguish a technological species' native habitat is the context of use in which it *evolved* and in which context it has a successful interrelationship with other "species," including humans. For instance, I've faced a lot of challenges carrying my portable LCD projector around in South Asia. It fits best in an ecosystem where there is reliable power (with minimal voltage spikes), where people use compatible video cabling standards, and where there are people who are literate in English and have computers to use it. In addition, ideally it should be close to stores that sell accessories such as bulbs and close to people who can repair it, and it operates in a climate that doesn't exceed the operating temperature of the device. Oh, and it shouldn't be exposed to too much dust. My projector quickly died in rural Himalayan villages and never "reproduced" (I gave up buying and/or bringing projectors there).

A technology might not have a single "habitat," either; it could be "native" in a variety of places. Like a migratory bird, a technology has various geographic ranges at different points in its life cycle. My laptop might require a design infrastructure in California, a manufacturing infrastructure in Taiwan, a fossil fuel infrastructure in the Middle East, an economic infrastructure in my hometown,

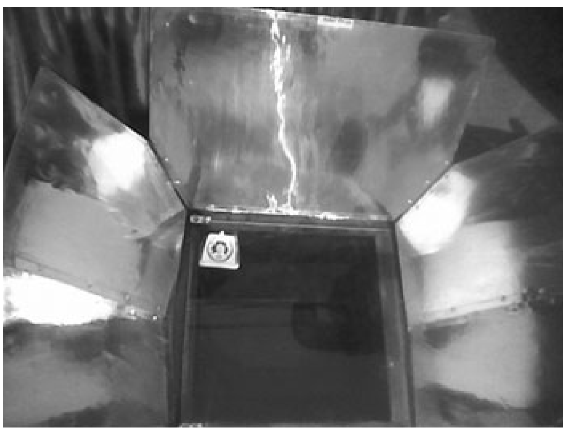

FIGURE 4.5
A solar cooker box from Nepal.

and finally, a disposal infrastructure in Africa, as toxic waste. Harm to any of these habitats threatens the survival of the "species" of laptops. Sadly, because the toxic waste portion of the life cycle represents an invasive phase, laptops as we know them might not be sustainable. Eventually, this factor will exert evolutionary pressure on laptops, and they will have to evolve (to be able to end up somewhere for recycling or disposal at the end of their lives) or perish.

Which brings us to the issue of reproduction. Members of a species can reproduce, but a device almost certainly won't, at least not through biological reproduction. Yet technologies do reproduce in the sense that they proliferate and in some cases die off. When my cordless phone breaks, I buy another, and the new version probably won't be sufficiently different from the previous one to be called a new species. Of course, one key difference between technology species and biological ones is that the former can undergo very rapid evolution (within one generation, even) and can undergo Lamarckian evolution—for instance, when I add a new processor or RAM to my computer. Still, when I think of most devices I've had over the years—blenders, wristwatches, automobiles, and even computers—it's the continuity between generations rather than the differences that come to mind (can you even remember the number of telephones you've had in your life?). And, similar to biological reproduction, technological reproduction requires inputs of energy and resources from the ecosystem (recall the school computers in Uttarakhand that were broken and never replaced).

What are the native species of technology in the developing world, and how have they emerged? There is a nice parallel between the slow pace of evolution in, say, an isolated island ecosystem and the slow pace of technological evolution in much of the world. Indigenous technologies such as irrigation techniques, housing construction techniques, and so on have come into being over many (human) generations and have done so within the "ecosystem" of practices within a particular culture. As with biological ecosystems, one profound disruption can permanently change the balance of species—for instance, the shift in India from copper water vessels to steel or tin later and to plastics now. But interestingly, the functional niche filled by, for instance, a plastic bucket is not so different from that of the tin bucket. Each of these devices does, in fact, coexist in modern Indian society. There are, of course, differences in their natural sources of energy and raw materials, and if somebody outlawed the use of plastic water vessels, steel and copper would undoubtedly resurge. This is another important distinction between problematic invasive species and those that, though nonnative, don't significantly disrupt the ecosystem in which they are "planted." We could debate whether the original putty-colored PCs, designed for use in an office environment, were an invasive species when they made the leap from workplace to home. Eventually, the computer in the den underwent evolution that office computers didn't; the original iMac, with its curved lines and bright colors, would have looked out of place in an office but was more suitable to homes, where fashion and color were valued.

So, invasive species can become a problem when they make life bad for other species in the ecosystem, but this might not always occur when a nonnative species arrives in a new place. Ecologists talk of stages in the invasion process: from transport to a new location, establishment of these "propagules" in their new home, spread of the species, to impact on the ecosystem as a whole (Lockwood, Hoopes, and Marchetti, 2007). Many more species fail to make the leap at each stage than continue on, and it's only when a species reaches the final stage that it can be considered invasive. Typically, invasive species displace local species (to the point of extinction in some cases); they reduce the biodiversity of the ecosystem, and they can lead to a diminishment of resources and ecosystem health. As Lockwood et al. point out:

> Viewing the invasion process as a series of stages has a couple of key advantages. First is the recognition that it is something of a misnomer to label a species as invasive or not. Individuals of particular species are transported and released into new environments, and it is this set of individuals that must survive and reproduce if the non-native population is to persist. In cases where individuals of one species have been transported to a variety of different places, it is possible that some of these incipient populations established, became widespread, and affected native biota (i.e., became invaders), while other populations did not.

In the case of technologies, we can observe cases in which a technology is moved to a new place but fails to take root—for instance, a dam put in place by a development organization might very well be neglected and eventually fall to ruin if it fails to establish itself within the local ecosystem of technologies. Similarly, my imported LCD projector might perish as quickly as an orchid planted in Antarctica. The movie *The Gods Must Be Crazy* provides a humorous example; in this film a cola bottle is dropped from an airplane and picked up by tribal villagers. As they try to figure out what the bottle is used for, it causes a series of negative (and hilarious) disruptions to the local society, to the point where the villagers decide that the bottle must be disposed of. By eliminating the lone member of this "species," the villagers exterminate it from their environment and (one assumes) can try to resume their normal activities. The bottle failed to "colonize" the new turf in the movie. In real life, Coca-Cola and Pepsi logos are found in the most surprising rural places; the bottle brings with it opportunities for other species of technology such as bottling plants, advertising signs, and even money itself, which might have had limited use in a subsistence agricultural, barter-based setting.

How technological species spread

Globalization is a key force in both the technological and biological spread of invasive species. Without contact, transport, and so on, species might move or take over new regions, but they would do so at a snail's pace. In the biological realm, it's estimated that human transportation increases the rate of introduction of species to new places by many orders of magnitude. A National Research Council report found that native (prehuman) plant species on Hawaii probably arose from about one species colonization every 100,000 years; with Polynesian settlement of the island, that rate increased to one species arriving on average every 50 years, and finally to one every 22 years since European settlement (National Research Council, 2002). Obviously, with air travel and acclimatization groups, this rate could increase even more markedly.

On the other hand, quarantine processes could slow arrival of invasives. Such techniques are used to prevent, for instance, the introduction of rabies to Britain or the medfly to California. The *Star Trek* science fiction TV series provides an example of a technological analogue, the "prime directive," in which technologies are quarantined from alien societies until the societies have developed, indigenously, the ability to travel to other star systems. In real life, people tend not to quarantine technologies but to try to distribute them as widely as possible; how else could we explain the existence of international standards bodies?

One rare example of technological quarantine is the nation of Bhutan's policy that deliberately chose not to license television stations until the 1990s; officials feared that the technology would disrupt local culture. Bhutan explicitly devalues the profit motive by emphasizing "gross national happiness" rather than gross national product and makes policy decisions accordingly. Interestingly, in the past this policy meant limiting foreign interaction to minimize exposure to foreign goods that would increase the population's covetousness, but isolationism is no longer perceived to be a viable way to maintain the nation's cultural/technological "ecosystem." Currently, the country is opening up to trade and interaction while still keeping tabs on which influxes of technology lead to better, as opposed to more miserable, lives on the part of the average Bhutanese.

Human introduction of new species is classified by ecologists as deliberate or accidental, and perhaps surprisingly appears to happen at a rate relatively constant with human movements from place to place. Deliberate introduction of species is done for reasons such as cash cropping (profit), making a new environment more like home for migrants (nostalgia), provision of huntable game (entertainment), and the euphemistic "biocontrol," or trying to change an entire ecosystem according to some desirable outcome, such as removing pest species. If we look to technologies, similar reasons emerge. For instance, a company might begin selling consumer electronics in a new market, or a businessperson might import a manufacturing technology to increase productivity (profit); an expatriate American might be interested in importing an automatic drip coffeemaker to Asia (nostalgia); media conglomerates might distribute games, television shows, movies, and other aspects of global culture (entertainment); or an organization might try to foster solar cookers to suppress the native "pest" of woodstoves (the analogy of biocontrol).

Impacts of invasion

Even in cases in which there is no deliberate attempt to introduce new species to cause them to flourish, we are often victims of bringing our species with us without considering how something we personally benefit from and that is relatively harmless in our usual contexts can be incredibly damaging in another context. For instance, the introduction of rats to Hawaii was an incidental byproduct of shipboard travel but was devastating to the local birds, which had no such predators in the past. Similarly, a business traveler might unwittingly pick up a computer virus in Hong Kong that infects her home office in Europe. Toilet fixtures brought in from a developed country might overwhelm the nascent plumbing infrastructure of a developing nation. Or someone might drop a soda bottle from an airplane, causing strife to an entire village. The ripple effects can outweigh the first-order effects of bringing new species to an ecosystem.

Competition is a good example of a second-order effect. In an ecosystem, species compete for the same resources, and a new species can impact the success of other species through competition. For instance, if two predators eat the same species, one or the other of the predators could dominate and cause the other to die out. A similar effect can be seen in a technological ecosystem. For instance, online social interaction through interactive Website online games competes with television for the attention and wallets of people seeking informal entertainment according to a study by Kraut, Kiesler, Boneva, and Shklovski, (2004). Interestingly, in the same study, viewing online news and entertainment sites alone was shown to increase use of television, showing that the particulars of competition in technological systems are just as hard to predict as in ecological systems.

Competition can also prevent a species from invading, if the local species have a survival advantage. For instance, for many years the use of SMS ("Short Message Service") or text messages on mobile phones in Europe was commonplace, whereas they were rare in the United States; SMS depended on mobile providers using the Global System for Mobile Communications (GSM) standard, and in the United States competing mobile standards that did not support text messaging, such as analog cellular, "preyed" on the same users. Even for those phone users who had GSM, it was difficult to tell whether other mobile users were capable of receiving text messages, so users turned to other alternatives for short messages, such as using a quick phone call or instant messaging on the Internet. The entrenched species of mobile phones helped resist the "invasion" of SMS due to competition for the same resources (mobile handsets and radio spectrum).

On the other hand, invasion ecology tells us that invasion often takes place after some sort of ecological disturbance. A fire, for example, could stress the local species in a forest sufficiently for nonnative plants to have an advantage. Similarly, the cessation of analog television broadcasting in the United States will all but wipe out the native population of televisions and is likely to enable liquid-crystal displays and plasma-based televisions to displace the older cathode-ray tube technology that is now the dominant "species" of display.

Disturbance is another example of a second-order effect, rather than a cause, of an invasion. For instance, when feral pigs were introduced into California by European settlers, they created disturbance by rooting and digging that significantly altered the soil, allowing nonnative grass species to colonize (Lockwood et al., 2007). When some technologies invade, they cause a massive disturbance to the technological ecosystem as well—for instance, electric lighting, the assembly line, or the printing press, each of which significantly altered the technological landscape.

Is there no upside to all of this? Indeed, where ecologists might begin with the presumption that nonnative species are inherently suspect, technologists have a key reason to be more optimistic: the speed of evolution through design, redesign, and adaptation. The incredibly short time span of technology evolution suggests that technologies can quickly become "naturalized" or "domesticated" in their new locations. It also suggests that native species, if given the chance, can evolve to coexist with the newcomers. Again, we have to question whether technology invasion and ecosystem change is a good or bad thing. People might mourn the loss of the dodo bird, but not the loss of the smallpox virus. Preservation and conservation efforts might try to maintain a pristine "old-growth" ecosystem as is, or they might focus on a more dynamic balance of species that evolves over time.

In general, the negatives of invasive species in ecology outweigh the positives. They can lead to extinction of native species; they can result in the temporary but unsustainable increase in utilization of natural resources through creation of disturbances; and they can displace keystone species (highly influential species on which many other species depend), essentially leading to ecosystem collapse or replacement. Invasive species, contrary to what you might expect, are more likely to take root when there is a diverse set of native species (Lockwood et al., 2007). Taken in the abstract, it might seem like simple survival of the fittest. But it is important to consider that humans form a part of the ecosystem, and we might find ourselves quite unhappy with a major shift in the web of relationships on which we depend. Technological invasives could be thought of in the same way; they can lead to wholesale replacement of native with nonnative species and/or ecosystem degradation. As research on ethnobotany and indigenous medicine shows, there might be native technologies that would be widely appreciated if they can survive the pressures of invasive technologies.

Alternatives to invasive technologies

I return to the example of the desktop computers in those Himalayan schools. The technologies are clearly nonnative in that they are not designed in, for, or through the rural village context. Their ecological "niche" was and still is the Western office environment, with limited evolution since expanding their "range" to encompass the dens and living rooms of developed nations. They require resources that are not abundant in India, including money, electricity, and, in this ecosystem, petrol for generators. They compete with teachers, field trips, and books for money; they compete with things like nighttime illumination or radios for electricity. And the use of petrol in the generators produces waste such as noise that creates disturbance (both in the ecological and literal sense) for people and animals in the local area. Nonnative species such as office furniture, printer supplies, and locks are brought in, further disrupting the local technological ecology. It seems fairly likely that these few instances of an ill-suited species will eventually go extinct in this place, but if not, they will cause disruption in the local technological ecosystem.

Yet many would argue that this is the exception that proves the rule: Technologies are a failure unless they are, in fact, invasive. (The phrase "killer app" fits right in with this model of "Invasive = Successful.") But what if we design our systems to overcome these barriers as well as possible?

The so-called "$100 laptop" project (later renamed the One Laptop Per Child, or OLPC, project when the device costs proved to fall closer to $200 or $300—see Chapter 11 for more details) is a good example of a technology that was created to be as invasive as possible. The project's *XO* laptop was specially designed to fit niches with a wide variety of power availability (similar to a drought-resistant plant), consuming a tiny 3 watts of power, an amount that could be provided via solar or hand-crank generators (another set of nonnative species). The laptops are designed to be dust-resistant, easily repairable, and usable in either sunny or dark environments, with an innovative screen that converts from reflective to transmissive display. The cost, obviously, also allows them to "survive" in a wider variety of locations than other traditionally priced desktop or laptop computers. The computers are mesh-networked, allowing them to get networking from each other rather than a specialized local area network (LAN) or wide area network (WAN). Where typical computers might "feed" on an Internet service provider (ISP), the XO can feed on ISPs, LANs, or each other. In short, they are flexible and can fit a wide variety of environmental conditions. As ecologists have discovered, suitability of the nonnative is only one factor involved in success; another is the availability of a lot of propagules or a regular influx of large numbers of the invasive species. The OLPC project has publicly committed to entering only countries where the government agrees to buy millions of the devices (Buchele and Owusu-Aning, 2007). In short, the device is in many ways a perfect "ecological engineer" or invasive species.

But will this achieve the desired goals? The XO laptop has not evolved in the ecosystem into which it is being inserted. In many of the countries courted by the OLPC project, the cost of a few hundred dollars per laptop might be equivalent to the per capita GDP. Consider this: If your goal is development, would it have greater impact to buy all the children laptops (which have a variety of resource dependencies within the local technological ecosystem) once or to pay every adult in the country to do something for a year? What types of learning will the laptops produce that can feed other economic, intellectual, or technological processes in the local ecosystem? It's clear they can consume resources, but what or who is the local beneficiary or predator of these laptops?

XO laptops run a custom (albeit open source) operating system. There is little software written for them, and the tremendous job of creating locally relevant content for the platform is a cost that the laptops will pull in, just as the desktops in India pulled in costs for furniture and remodeling. Can we look the parents of Uttarakhand in the eye and tell them this technology supports their local values any more than the desktop computers did?

As with biocontrol and deliberate ecological engineering, we have to remember the ripple effects our technologies might engender. I've been in villages where four or five families have a television or radio; people gather in large groups to listen to the radio or watch the TV together, and rickety 16 mm projectors are still pulled out to project a movie on a bed sheet, even as a local DVD or VCD player sits unused. Collaborative, shared experiences are an important characteristic of local use of technologies. One Laptop Per Child emphasizes in its very name the opposite—individual ownership and use of technologies. Will this disrupt the local web of relationships that allow people and technologies to coexist in a stable mutual dependence? I don't know, but just as an agriculturalist might think twice, thrice, or more before introducing a nonnative species for pest control, I think that we as designers need to move carefully in trying to introduce one nonnative technology species to solve a problem with a local ecosystem, knowing full well that the ripple effects of such introductions are hard to predict and introductions are nearly impossible to undo. Prior attempts at changing children's lives through non-native technology have not fared well (e.g., Brand and Schwittay, 2006).

What is our alternative? Within the ecological metaphor, we could talk of restoration and searching out native species that serve local needs. But here is where the differences between the ecological metaphor and technological reality are truly helpful. Because technological evolution is a deliberate rather than naturally occurring process, we can try to envision ways to create new, native species that would solve local problems. Various technologists have explored the use of participatory and informant design techniques to involve children or user groups (Muller and Kuhn, 1993; Scaife, Rogers, Aldrich, and Davies, 1997; Druin, 1999).

In general, these methods respect the need for inputs from local participants. But including local needs in the design process is only one part of our definition of making a design truly native. What we need to do is to iterate and evolve technologies in context as rapidly as possible. A fantastic example of this type of process is the Kinkajou project run by the nonprofit Design that Matters. Through extensive revision in context, with wide participation, what began as a laptop-like concept for literacy in rural Africa was transformed into a sealed, low-power microfilm projector containing 10,000 pages of relevant literacy materials that evolved in the local context ("Design that Matters," Silver-Greenberg, 2005). Rather than treating technology as an exported good, we should consider what evolutionary processes take place in the contexts we care about and try to evolve the local species—whether technological or human. This approach has been used for some time in workplaces in the West (Allen, 1993).

The differences between developing and industrialized countries, or between adults and children, have been used as an excuse to avoid full engagement with design in context in these cases, yet it is these very differences that suggest we need to look for "native" solutions to problems in those contexts rather than trying to fashion some optimal "invasive" species. In the case of developing nations, increasing the capacity for local innovation and evolution to take place should be a key focus (see, for instance, Nokia's efforts: Jung and Chipchase, 2008). And in the case of children, we need to systematically break down the barriers that prevent some of the most innovative, creative, and determined members of our population—children—from innovating and inventing the future of their own ecosystem (Gayeski, 1981; Kam et al., 2006). Involvement should be a key focus, "making technology part of 'who they are and what they do'" (Merkel et al., 2005). Perhaps most important, everyone involved in the design process needs to think like ecologists do, systemically and holistically, while realizing that the complexity of the systems we hope to improve demands, rather than an iron will, the patient hand of evolution over time and an unwavering vision of the technological future in a particular context.

Connecting to you

- Whether a technology is "bad" or "good" depends on how it fits into its context of use.
- Adoption and spread of a technology are negatives when the technology displaces or degrades the local technological "ecosystem."
- When introducing technologies, be cautious about second-order effects of those technologies.
- Where possible, look for improvement or iteration of "native" technologies in a setting rather than bringing in technologies from another setting.
- New methods are needed for designing mobile technologies that consider context, culture, and needs.

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