"Stimulate progress but preserve the core."
Collins and Porras, *Built to Last*

3 Identifying, Nurturing and Monitoring Core Technologies

Having already defined high technology and the commercialization cycle, we must finally define "technology" and technology transfer. We then move to the criteria for choosing and identifying core technologies. (Chapter 1 established the justification for distinguishing core technologies). One criterion is the ability to master the core technology fast enough to reduce prices in a way that maintains profitability while discouraging competitive entries. Experience curves are an important consideration in timing price reductions; this chapter deals with experience curves and their computation. Again, the requisite mathematics are given in an appendix.

Outsourcing non-core technologies implies becoming a virtual organization. A focus on evolutionary and open-systems theory – a view of high-technology firms as evolutionary organizations – clarifies how even core technologies must be re-evaluated over time.

3.1 Defining Technology and Technology Transfer

Technology is knowledge used in design, products, manufacturing processes, organizations, training, software, etc. Preferably, this knowledge is *reproducible*, *realizable in devices,* and *transferrable.*

It must be reproducible because technology stems from science, and science rests on reproducible experiments – rather than on non-reproducible knowledge like sorcery or some kinds of artistic talent.

While the word technology implies that much of this knowledge is embedded in machines and tools, the knowledge needed to build and operate these machines must also be considered part of the technology. Below, when we explore core technologies, we will want to separate this kind of knowledge from knowledge used to turn core technologies to business advantage. This latter kind of knowledge is called *core competencies.*

Finally, technology should be transferrable. *Technology transfer* is the process of converting knowledge from on use to another – for example, from defense to civilian use, from research to application, and so on. The term technology transfer ("T^2," to cognoscenti) is especially important as it relates to transferring knowledge from its usage in one organization to another use in another organization.

3.2 Core Technologies

A company's core technologies should give it a distinctive competence. They should give the company a relatively secure distinction, at least for a period of time that is financially sensible. Core technologies should be:

1. state of the art;
2. fully tested and debugged;
3. well protected through patents, trade secrets, application know-how and a stably employed technical staff; and
4. relevant to the marketplace.

The technology should be relevant to the marketplace both in its essential appeal to customers and in its superiority to competitors' offerings. It should be well past laboratory stage and truly ready for application. These three traits have been called "market criticality," "technology competitive position," and "technological maturity," respectively.

Ideally, core technologies will have still more characteristics:

5. When core technologies are matrixed against the company's products, as in Table 3.1, the matrix should be dense. That is, core technologies should be highly relevant to the firm's products.
6. There should be few ready substitutes for the technology.
7. Preferably, the core technology is basic in the sense that it will spin off many new capabilities; even better if these new capabilities are also easily protectible.
8. The cost and availability of people to sustain the core technology should compare favorably against the ease of outsourcing the technology.

9. They should expose the firm minimally as regards regulation and legal risks.

Table 3.1 Which Core Technologies Are Used in Which Products? (Art courtesy of Cenquest, Inc.)

The Firm's Products

The Firm's Core Technologies	1	2	3	4	5	6	7	8	9	10	11	12
1	X	X		X		X				X		
2		X	X	X	X	X		X				
3	X			X	X	X			X			
4	X	X	X				X					
5			X	X				X				
6												

The differentiating (core) technology may be superior product engineering (Mercedes-Benz), superior product design (Sony), superior user interface (Apple, Palm Computing), or superior management of channels and marketing (Dell Computer). The firm should understand how this differentiating competence affects the bottom line, and how long the advantage may last. Dell, for example, knows the detailed impact of its fast order/delivery cycle on customer buying patterns and on inventory and component costs, and benchmarks these conscientiously against Compaq and others. But Dell still (either from fear their advantage would not last, or just as an ill-advised foray outside their core competence) botched an incursion into retail outlet selling.

The company must take care to distinguish core technologies ("differentiators") from "facilitators" (technologies which everyone must have in order to compete in the industry at all). For example, a management school dean must have a good office LAN (facilitator), but that by no means ensures success for the school; success is made likely by having a differentiator – like one of the finest technology management faculty in the world.

Core technology is a relatively new concept that replaces older business philosophies (see Figure 3.1). The Figure shows that it is a future-oriented concept. But we shall see later in the chapter that a firm may choose or be forced to review its core technologies as technological and market forces change.

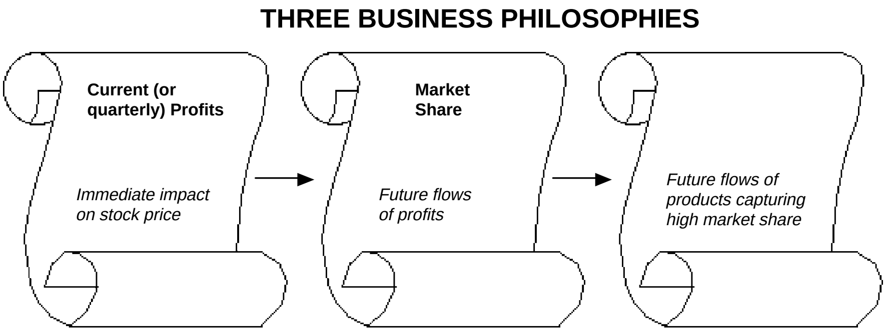


Figure 3.1 Steps in the evolution of business focus and philosophy

The Core Technology Strategy Applied in Japan

Previously, Japanese competitive advantage arose from inter-departmental cooperation within a company. For example, production costs were reduced because product research and development were conducted with manufacturing in mind.

"Companies that succeed in fully exploiting their own technologies for competitive advantage will be in a position to lead high-tech industries, dominate already established markets, or create new markets. Conversely, companies that fail to exploit their technologies appropriately can find themselves in serious competitive difficulty."

Many companies have started "2000 Vision" projects that will identify core business technologies, customers, and product functions.

Many Japanese companies have held on to some technologies for too long.

Even where these projects have not yet been successful they have raised the awareness that technologies must be understood "in the context of the market".

Core technologies shift over time; technologies picked now can have an influence for some time to come across several product lines.

How are core technologies managed?.

– Companies focus on a wide number of technologies. For example NEC has selected 30 core technologies, Canon 21.

– The challenge is to balance company-wide benefits with the business unit benefits.

- In the past, R&D was under a business unit which created organizational walls that inhibited sharing of technologies.
- Some companies have solved this problem by creating a company committee for each technology. This committee reports to corporate and has control over human resources company wide. It is responsible for long range planning, dissemination of information, and training.

Kokubo A (1993) Core Technology Based Management: The Next Japanese Challenge. Prism / First Quarter, Arthur D Little. Summary by Michael Funk.

Selling the Family Jewels?

IBM has developed a business model in which the company can increase its profits and sharpen its technology development by selling its core technologies.

Ira Sager's prime example is what he calls IBM's hottest growth business. "The Big Blue technology boutique" is a business direction in which IBM is selling components developed for its own systems to other companies, including its rivals for systems business. IBM is selling components such as disk drives, microprocessor chips and the little eraser-like pointer used in ThinkPad notebooks to competitors such as Hitachi, Apple Computer, and Canon. In this way, even when IBM loses a computer deal to one of these competitors, it still makes money on the components in their system. As Sager says, "Short of winning every deal, you can't beat that."

Selling components to competitors keeps IBM's factories busy and forces IBM to sharpen its technology by putting it in competition with the world's top component makers, while adding dramatically to revenues. License fees added $3.6 billion in revenue in 1994, with a growth rate one hundred times that of the entire company in the second quarter. Licensing protects IBM's intellectual property, and provides strong returns on the company's R&D budget, which was in the past folded into IBM's new products. And, if IBM can make the latest technology at the right price for competitors, it will also be creating the most competitive technology for its own computers.

As much as pursuing the component market makes sense, it can't restore or replace IBM's core business. At 10%, gross profit margins for components are only about a third of IBM's overall profit margin – better than no business at all, but not enough to turn IBM around.

Sager mentions that Hitachi's endorsement of IBM chips boosted IBM's efforts to make the PowerPC an industry standard – in which IBM ultimately failed.

Sager I (1994) IBM Knows What to do with a Good Idea: Sell It. Business Week September 19. Summarized by Cheryl Coupé.

In times of technology convergence, it is more difficult to determine a company's core technology and core competence. When a retailer builds a website, is the retailer in the software business? When a gas pipeline owner begins to carry fiber optic in the pipe, does it become a telecommunications firm? When a variety of technologies (inkjet, bubblejet, laser) can cheaply produce color copies, should a diversified firm with a laser printer operation stay in the market? Recently Tektronix decided "no" on this last question, spinning its color printer division off to Xerox. Another example (see the box below) is Texas Instruments.

Now, TI means "taking initiative."

Texas Instruments is re-examining its core businesses, assessing the real value to their customers and stakeholders. They are re-engineering how their company contributes to their customers and, more importantly, to the end-user.

TI is repositioning itself from a "demand-based" integrated circuit manufacturer/provider to a company that is out to create demand for their products by influencing the way in which IC's will be used. They are helping their customers to innovate, moving away from being a silicon provider, and upward on the value chain. TI took their patented digital mirror device (DMD) technology and contracted with Asian TV screen makers to develop surfaces that take advantage of DMD's higher resolution. Their prototypes from portables to wall-size home theaters grabbed the attention of projection manufacturers.

TI is fostering tighter connections with their customers, promoting innovation to help create billion-dollar businesses. Through their Digital Signal Processor (DSP) technology, TI developed and incorporated processes to allow for customers to hand-tailor their DSPs to include memory, power, and logic. This led to a ten-year, 600,000 DSP contract with Sony for use in the Boeing 777's audio systems.

TI is drawing a hard line when it comes to deciding in which markets to compete. Size and return on assets (ROA) are the drivers for determining the company's ongoing efforts. The manager of TI's notebook PC unit was given a mandate to increase sales to $1 billion while achieving 20% ROA, or else sell the unit.

Burrows P and L Holyoke (1995) Now TI means 'taking initiative.' Business Week May 15. Summarized by Mike Miles.

3.3 Experience Curves

In the late 1940s and early '50s, it was noticed that the cost of manufacturing airframes (aircraft bodies) decreased after several had been completed, even though labor rates and materials costs did not decrease. It was thought that employees were devising or learning better ways of assembling the craft, as they became more familiar with what was required. The trend in cost was called the "learning curve."

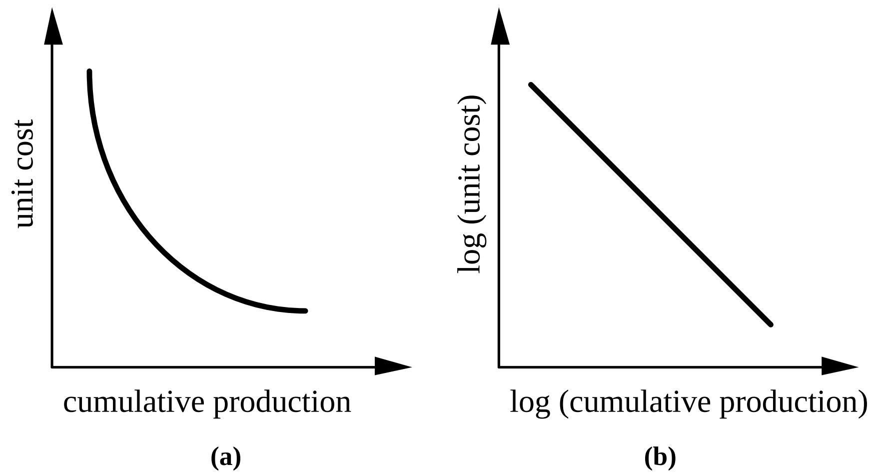


Figure 3.2 The experience curve phenomenon: (a) The cost of manufacturing one unit declines steadily as production experience increases. (b) The cost trend is becomes a straight line when graphed on log-log paper.

It was then noticed that when there was turnover in manufacturing line employees – costs decreased anyway! Because decreased costs were now evidently not a pure effect of individual learning (it seemed, rather, that employees were teaching other employees what they had learned), the graph of Figure 3.2 was renamed the "experience curve." The phenomenon was observed in many other manufacturing settings. The Boston Consulting Group and others noted its effect in petroleum catalytic crackers, in polyvinyl chloride production, in electric power production, and in the brewing of beer.

There is controversy as to whether declining unit costs are due to *the firm's collective experience* in producing the item; or to *economies of scale*. In the latter case, costs would be a function of the production level at a given point in time, rather than of cumulative production since the product's launch. In any event, it has been verified in a variety of empirical cases that unit costs drop by a fixed percentage every time cumulative production doubles.

$$\log(\text{Unit Cost}) = -b \log(\text{Cumulative Units}) \Rightarrow \text{Unit Cost} = (\text{Cumulative Units})^{-b}$$

In an "80% learning curve," unit costs fall to 80% of their previous level every time production doubles. For an 80% learning curve, $b = -\log(0.8) / \log(2)$.

A company's product becomes part of its customers' production processes. The customer must learn to use the product productively. If a steep learning curve (that is, fast learning, or simplicity) is *built into* the product, the take-off point in the product's demand cycle will occur sooner. So producers of industrial products must think about the "learning burden" involved in using their products.

All electronics-related companies must be thinking about when to drop prices. A price reduction – however it might be despised by stockholders – prevents competitors from taking market share, signals the imminent introduction of a newer and more capable product generation, and allows the new generation to be priced affordably yet still be seen as a big improvement in price-performance relative to the older generation. Figure 3.3 shows how the timing of price reductions is not only a fundamental strategy of the firm, but depends (inter alia) on experience-based cost reductions and on the expected actions of competitors and potential competitors.

The U.S. home appliance industry is a good example of "strategy A," i.e., reducing prices in synch with reductions in cost. This industry has always operated on thin profit margins. Add to that the fact that refrigerators are big and expensive to transport. The result is that although you (if you live in the U.S.) may drive a Japanese car and watch a Japanese TV, you do not have a Japanese refrigerator, air conditioner, or dishwasher!

In electronic markets, where prices are generally declining, the question of when to drop the price is a very fundamental one. Intel Corporation's practice is to drop prices on its higher-end microprocessors in anticipation of its competitors actions, while maintaining prices on the older microprocessors in order to (first) get customers to see upgrades as economical and (second) to squeeze competitors. This strategy is best used by a company that, like Intel, is first to market in each generation. Intel bases its price decisions on three things.

- First, its readiness to introduce a new generation of microprocessor.
- Second, its decline in manufacturing costs as reflected in the experience curve.
- And third, its anticipation of competitors actions.

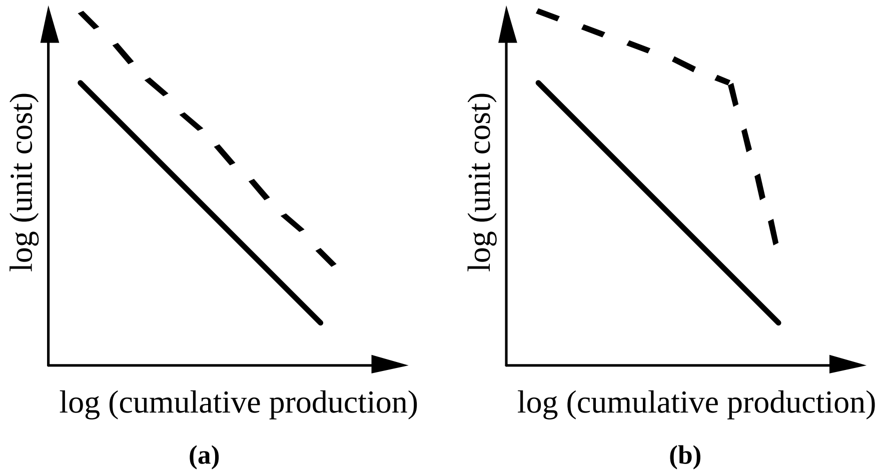


Figure 3.3 Pricing strategies: (a) yields small margins but prevents competitive entry; (b) is profitable until competitors enter but necessitates sharp price cuts after followers enter the market. Dotted line denotes price; solid line is cost.

The Technology Paradox

To survive and compete in today's business world, companies are following new sets of business rules: making money by giving things away; low prices and high volume; mass customization; shared technologies – and the faster the better.

Business thrives when prices are falling the fastest, because more people can afford to buy at each stage of price reduction. Also, companies can afford to give away the previous generation of hardware while making money on upgrades or service. The only thing that matters to these companies is that the exponential growth of their market is faster than the exponential decline of their prices.

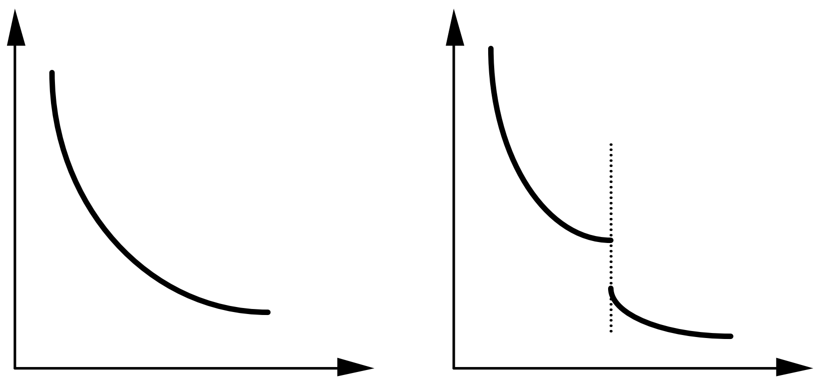
Companies no longer focus on product alone; they focus on integrating many products in a common architecture. New products then don't require a new architecture, but must fit into an existing one. In integrated circuits (ICs), chipmakers' architecture strategies let them efficiently develop competencies in software and electronic components by focusing on the limited tasks in those areas that are demanded by their generation-spanning architectures.

These and other companies will mass-customize. American companies developing with multi-function chips hope to outperform Japanese firms – which tend to use single-function devices that are hard to customize – in mass customization. "Tomorrow's factories will sell customer gratification – not things."

Gross N and P Coy (with Otis Port) (1995) The Technology Paradox. Business Week March 6. Summarized by Annie Leong.

Because we've talked so much about technological innovation in this book, it is important to understand that the learning effects we saw on the experience curve do not involve innovation. The experience curve reflects declines in production costs using a fixed set of technologies. It does not reflect anything about using new, more effective technologies. But innovations do and should occur. So, how does innovation affect the experience curve?

In Figure 3.4, the experience curve looks odd, because we are not using logarithms on the axes. In view (a), you can see a normal decline in costs as manufacturing experience increases. In view (b), the graph shows one concept of how an innovation could effect the experience curve: There is a sudden drop in cost, but then the learning effect resumes at the same rate as before. In view (c), there is a second possible way that an innovation could effect the learning curve – by a sudden shift in the slope of the learning curve. In view (d), we can see how an innovation might temporarily increase costs during the period of time when everyone on the manufacturing floor is adjusting to the new procedure, but once underway, the new procedure increases productivity (decreases costs) at a faster rate than before the change.



(a) **(b)**

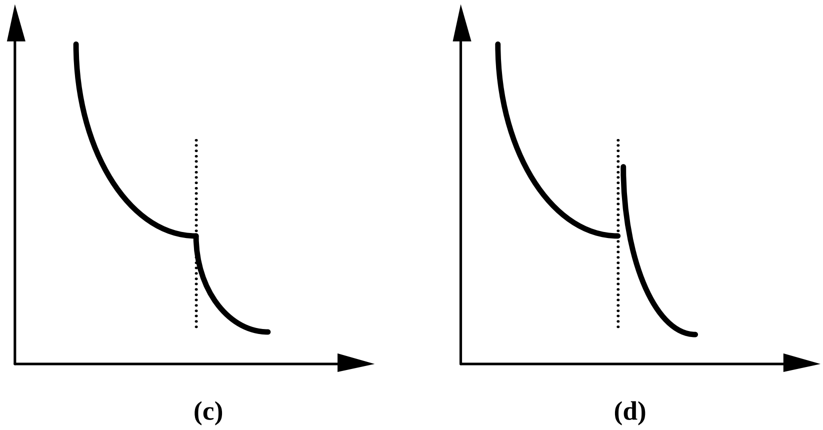


Figure 3.4 Innovation as an experience curve phenomenon: Three views
(a) Unit cost drops with cumulative production even in the absence of innovation.
(b) Innovation causes a sudden drop in cost; the same experience curve then resumes.
(c) Innovation causes a shift in the slope of the experience curve.
(d) Innovation causes a short-term productivity loss (increase in unit cost) followed by experience gains at a faster rate than before.

Now let's look at an example of how this works in the real world. The following is from a real company, and is quite typical.

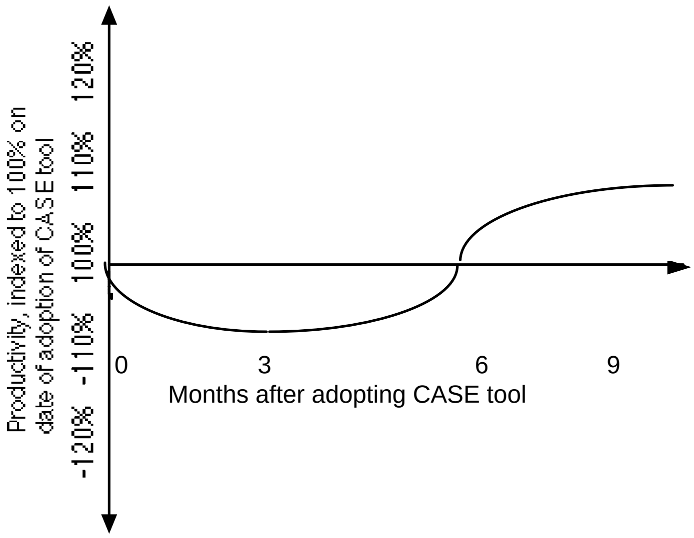


Figure 3.5 Productivity loss and recovery after adoption of a new technology

Figure 3.5 shows the productivity of software development, in terms of number of lines of code per person per day, just after the developers began using a computer-aided software engineering (CASE) tool. During the six months following the adoption of the tool, productivity dropped off. After that, productivity increased beyond what it was at the time of adoption of the CASE tool.

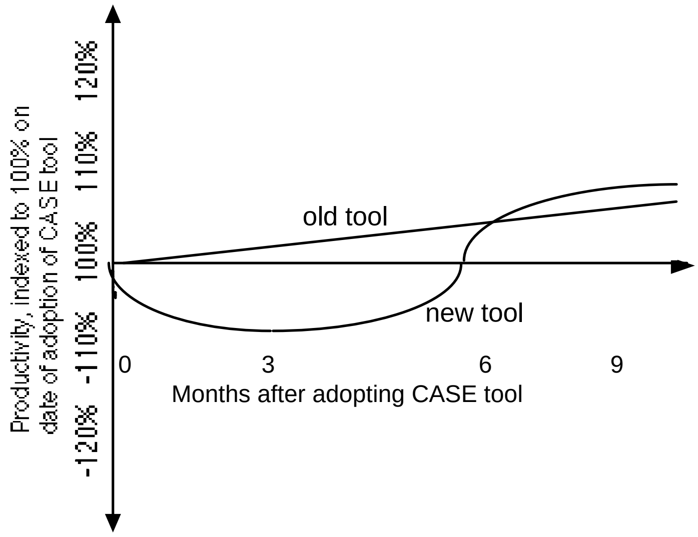


Figure 3.6 Productivity would have increased anyway (straight line), even if the new tool (curved line) had not been adopted. A buyer hopes the two lines will cross, and long-term productivity benefit will result from the new tool.

Where would net gains begin? Obviously *well after* 6 months of using CASE tools, for two reasons: First, it takes time to make up the losses that occurred during the 6 month learning period. Second, keep in mind that under an ordinary learning curve, code productivity would have increased even if the CASE tool had *not* been adopted. So the break-even point will occur well after the sixth month.

Naturally, this CASE tool was marketed as a boon to productivity. Do you think the vendor of the CASE tool told customers that adopting this product would torpedo their productivity for at least the next six months? I doubt it! We might expect the vendor to say that this tool will increase your productivity tomorrow – which should be a warning for all of us who sell productivity solutions!

3.4 High-Technology Firms as Evolutionary Organizations

A company's technological focus may have to change. The change may be forced by evolving customer tastes, or by technological change. Sometimes this technological change takes the form of technological convergence, as was the case when Microsoft almost got blindsided by the Internet. (Microsoft had been planning consumer services based on a dial-up service analogous to the pre-Internet America Online.)

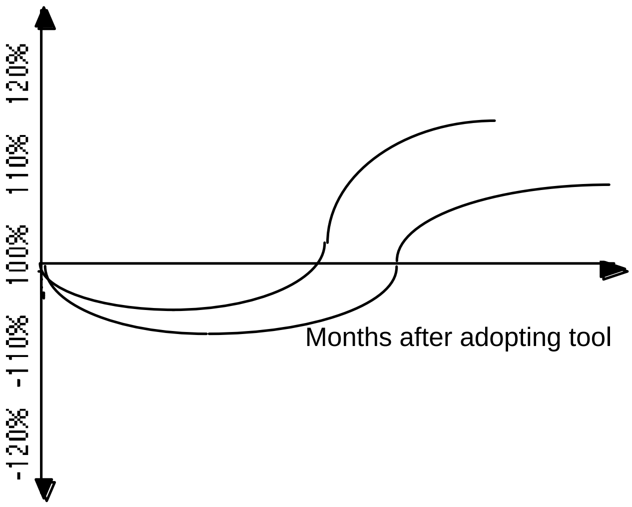


Figure 3.7 Vendors can gain advantage by designing tools that give the buyer a smaller short-term productivity hit, faster recovery of productivity, and a bigger ultimate increase in productivity.

Intellectual Capital

•Even the most modern accounting methods only track material assets and expenditures, but many business experts believe modern corporations have more intellectual capital than tangible capital – usually 3 to 4 times the tangible book value. Measuring intellectual capital has proven elusive, but most companies can tell when they have improved their use of it.

• Ernst &Young consultant Larry Prusak's definition of intellectual capital is similar to our definition of technology: "intellectual material that has been normalized, captured, and leveraged to produce a higher-valued asset."

• Dow Chemical is one of many companies to create a position "Director of Intellectual Asset Management." The current Director allows that "art and know-how" are part of intellectual assets, but has started with an easier task – organizing Dow's handling of its 29,000 patents. He found Dow and other companies have large inventories of unlicensed but potentially valuable patents. He developed a six-step program for dealing with a firm's patents:

1. Define the role of knowledge in your business.

2. Assess competitors’ strategies and knowledge assets.

3. Classify your portfolio (of patents) by use, potential application, etc.

4. Evaluate. What are the costs, potentials, effort needed to realize potentials? Keep ‘em, sell ‘em, abandon ‘em? (Keeping a patent in force over its lifetime can cost $250,000 in legal, filing fees, taxes, etc.)

5. Invest. Invest in in-house and needed external technologies.

6. Assemble your new portfolio and repeat.

• Attend to how knowledge workers interact, and provide systems to facilitate. Manage “both content and culture.” Study how to keep from “losing the recipe” when workers leave the firm or work groups reorganize.

• Distinguish intellectual assets that go home (knowledge in employees’ heads) from those that stay on-site (databases, networks, libraries, etc.)

Stewart T A (1994) Your Company’s Most Valuable Asset: Intellectual Capital. Fortune (October 3) 68-74

A widely acclaimed Stanford University study identified the management practices that are common to very long-lived companies. These are:

• The best managers are thinkers, not necessarily charismatic, and definitely not micromanagers. They believe in procedures and policies, but procedures and policies that admit some flexibility.

• The best managers transcend trade-offs, refusing to admit, for example, that productivity and quality cannot coexist. They persist until they achieve both quality and productivity.

• They stimulate progress,but preserve the core. Their cultures may be cult-like, but they are pragmatic, and set audacious goals.

• They send consistent signals, so stakeholders feel secure in knowing what the goals are.

The “Stanford Visionary Companies,” when compared to companies that did not share these characteristics, showed twelve times more share appreciation over the period 1926-1996. Apparently the research design did not include comparisons to the stock of companies that were sold, which conceivably could have netted still higher returns. But the visionary principles are appealing and the visionary companies’ financial returns are impressive!

Disruptive Technologies

David Isenberg (*WIRED*, August, 1998, page 78) says, "If you're listening to your customer, it's almost preordained that you'll miss the new market. And when the new market expands to encompass the old market.... that's when companies can become obsolete."

Isenberg is echoing the thesis of Harvard professor Clayton Christensen, who argues that technology B disrupts technology A if B...

• is initially of lower cost, quality, mark-up, and complexity than A;

• appeals at first only to the market segment that demands little in the way of performance;

• potentially offers qualitatively different kinds of benefits than A;

• rapidly improves in performance; and

• thus eventually takes over the higher-margin segments.

Management, leading customers, and stockholders initially disdain technology B due to its low quality and low margins.

The personal computer, "obviously a toy," disrupted the market for mainframe computers. Christensen shows how ever-smaller hard disks ("An 8-inch drive can't possibly be as good as a 12-inch drive") disrupted their predecessors.

We know that customers are good at saying what they want with reference to a known product, and are not good at saying what they want with regard to an unknown product. What does Christensen's concept of disruptive technologies really add to that ancient wisdom? "Only two things," Christensen says, "Your current leading customers will not be your future leading customers. And your future leading customers will come from the bottom of the market."

Nonetheless, his notion has entered the common vocabulary. Cherry Murray, a research director at Bell Laboratories, is working on miniaturized television devices (*Business Week*, Aug. 31, 1998, p.83). "They'll come in at the low end, not the high end," she says, "That's the disruptive part."

Christensen C (1997) The Innovator's Dilemma. Harvard Business School Press Boston