through a natural event like a drought or an earthquake, or by means of a government regulation.

Some authors restrict the term "diffusion" to the spontaneous, unplanned spread of new ideas, and use the concept of "dissemination" for diffusion that is directed and managed. In this book we use the word "diffusion" to include both the planned and the spontaneous spread of new ideas.

Controlling Scurvy in the British Navy: Innovations Do Not Sell Themselves

Many technologists believe that advantageous innovations will sell themselves, that the obvious benefits of a new idea will be widely realized by potential adopters, and that the innovation will therefore diffuse rapidly. Seldom is this the case. Most innovations, in fact, diffuse at a disappointingly slow rate.

Scurvy control illustrates how slowly an obviously beneficial innovation spreads (Mosteller, 1981). In the early days of long sea voyages, scurvy was a worse killer of sailors than warfare, accidents, and all other causes of death. For instance, of Vasco de Gama's crew of 160 men who sailed with him around the Cape of Good Hope in 1497, 100 died of scurvy. In 1601, an English sea captain, James Lancaster, conducted an experiment to evaluate the effectiveness of lemon juice in preventing scurvy. Captain Lancaster commanded four ships that sailed from England on a voyage to India; he served three teaspoonfuls of lemon juice every day to the sailors in one of his four ships. Most of these men stayed healthy. But on the other three ships, by the halfway point in the journey, 110 out of 278 sailors had died from scurvy. The three ships constituted Lancaster's "control group"; they were not given any lemon juice. So many of these sailors became sick that Lancaster had to transfer men from his "treatment" ship in order to staff the three other ships.

The results were so clear that one would expect the British Navy to adopt citrus juice for scurvy prevention on all its ships. But it was not until 1747, *about 150 years later*, that James Lind, a British Navy physician who knew of Lancaster's results, carried out another experiment on the *HMS Salisbury*. To each scurvy patient on this ship, Lind prescribed either two oranges and one lemon, or one of five other diets: A half-pint of sea water, six spoonfuls of vinegar, a quart of cider, nutmeg, or seventy-five drops of vitriol elixir. The scurvy patients who got the citrus fruits were cured in a few days, and were able to help Dr. Lind care for the other patients. Unfortunately, the supply of oranges and lemons was exhausted in six days.

Certainly, with this further solid evidence of the ability of citrus fruits to combat scurvy, one would expect the British Navy to adopt this technological innovation for all ship's crews on long sea voyages, and in fact, it did so. *But not until 1795, forty-eight years later.* Scurvy was immediately wiped out. And after only *seventy more years*, in 1865, the British Board of Trade adopted a similar policy, and eradicated scurvy in the merchant marine.

Why were the authorities so slow to adopt the idea of citrus for scurvy prevention? A clear explanation is not available, but other, competing remedies for scurvy were also being proposed, and each such cure had its champions. For example, Captain Cook's reports from his voyages in the Pacific did not provide support for curing scurvy with citrus fruits. Further, Dr. Lind was not a prominent figure in the field of naval medicine, and so his experimental findings did not get much attention in the British Navy. While scurvy prevention was generally resisted for years by the British Navy, other innovations like new ships and new guns were accepted readily. So the Admiralty did not resist all innovations.

This case illustration is based on Mosteller (1981).

Obviously more than just a beneficial innovation is necessary for its diffusion and adoption to occur. The reader may think that such slow diffusion could happen only in the distant past, before a scientific and experimental approach to evaluating innovations. We answer by calling the reader's attention to the contemporary case of the nondiffusion of the Dvorak typewriter keyboard.

Nondiffusion of the Dvorak Keyboard

Most of us who use a typewriter or who do word processing on a computer do not realize that our fingers tap out words on a keyboard that is called "QWERTY," named after the first six keys on the upper row of letters. The QWERTY keyboard is inefficient and awkward. This typewriter keyboard takes twice as long to learn as it should, and makes us work about twenty times harder than is necessary. But QWERTY has persisted since 1873, and today unsuspecting individuals are being taught to use the QWERTY keyboard, unaware that a much more efficient typewriter keyboard is available.

Where did QWERTY come from? Why does it continue to be used, instead of much more efficient alternative keyboard designs? QWERTY was invented by Christopher Latham Sholes, who designed this keyboard to slow down typists. In that day, the type-bars on a typewriter hung down in a sort of basket, and pivoted up to strike the paper; then they fell back in place by gravity. When two adjoining keys were struck rapidly in succession, they jammed. Sholes rearranged the keys on a typewriter keyboard to minimize such jamming; he "anti-engineered" the arrangement to make the most commonly used letter sequences awkward. By thus making it difficult for a typist to operate the machine, and slowing down typing speed, Sholes' QWERTY keyboard allowed these early typewriters to operate satisfactorily. His design was used in the manufacture of all typewriters. Early typewriter salesmen could impress customers by pecking out "TYPEWRITER" as all of the letters necessary to spell this word were found in one row of the QWERTYUIOP machine.

Prior to about 1900, most typists used the two-finger, hunt-and-peck system. Later, as touch typing became popular, dissatisfaction with the QWERTY typewriter began to grow. Typewriters became mechanically more efficient, and the QWERTY keyboard design was no longer necessary to prevent key jamming. The search for an improved design was led by Professor August Dvorak at the University of Washington, who in 1932 used time-and-motion studies to create a much more efficient keyboard arrangement. The Dvorak keyboard has the letters A,O,E,U,I,D,H,T,N, and S across the home row of the typewriter. Less frequently used letters were placed on the upper and lower rows of keys. About 70 percent of typing is done on the home row, 22 percent on the upper row, and 8 percent on the lower row. On the Dvorak keyboard, the amount of work assigned to each finger is proportionate to its skill and strength. Further, Professor Dvorak engineered his keyboard so that successive keystrokes fell on alternative hands; thus, while a finger on one hand is stroking a key, a finger on the other hand can be moving into position to hit the next key. Typing rhythm is thus facilitated; this hand alternation was achieved by putting the vowels (which represent 40 percent of all letters typed) on the left-hand side, and placing the major consonants that usually accompany these vowels on the right-hand side of the keyboard.

Professor Dvorak was thus able to avoid the typing inefficiencies of the QWERTY keyboard. For instance, QWERTY overloads the left hand, which must type 57 percent of ordinary copy. The Dvorak keyboard shifts this emphasis to 56 percent on the stronger right hand and 44 percent on the weaker left hand. Only 32 percent of typing is done on the home row with the QWERTY system, compared to 70 percent with the Dvorak keyboard. The newer arrangement requires less jumping back and forth from row to row; with the QWERTY keyboard, a good typists' fingertips travel more than twelve miles a day, jumping from row to row. These unnecessary intricate movements cause mental tension, typist fatigue, and lead to more typographical errors.

One might expect, on the basis of its overwhelming advantages, that the Dvorak keyboard would have completely replaced the inferior QWERTY keyboard. On the contrary, after more than 50 years, almost all typists are still using the inefficient QWERTY keyboard. Even though the American National Standards Institute and the Equipment Manufacturers Association have approved the Dvorak keyboard as an alternate design, it is still almost impossible to find a typewriter or a computer keyboard that is arranged in the more efficient layout. Vested interests are involved in hewing to the old design: Manufacturers, sales outlets, typing teachers, and typists themselves.

No, technological innovations are not always diffused and adopted rapidly. Even when the innovation has obvious, proven advantages.

As the reader may have guessed by now, the present pages were typed on a QWERTY keyboard.

Details on resistance to the Dvorak keyboard may be found in Dvorak and others (1936), Parkinson (1972), Lessley (1980), and David (1986a).

Four Main Elements in the Diffusion of Innovations

Previously we defined *diffusion* as the process by which an *innovation* is *communicated* through certain *channels* over *time* among the members of a *social system*. The four main elements are the innovation, communication channels, time, and the social system (Figure 1–1). These elements are identifiable in every diffusion research study, and in every diffusion campaign or program (like the diffusion of water-boiling in a Peruvian village).