

Chapter 14

Technology Diffusion



In Unit 3, we considered the development of new technologies to improve the prevention of infectious disease, the early detection of cancer and the treatment of cardiovascular disease. Through this journey, we have seen the often-integrated processes of scientific research, engineering design and clinical research in action. Through this coordinated process, we develop new health care technologies which are safe and effective. How do we ensure that the results of these efforts actually reach the patients who need them? In Unit 4, we will consider this important question, as we examine how new health technologies are managed. In Chapter 14, we will examine the diffusion of new innovations-what drives the adoption of technologies that are newly proven to be beneficial? How does the diffusion of new technologies differ throughout the world? How can we speed the adoption of effective new technologies?

The diffusion of new interventions has been historically slow. Consider the example of the use of vitamin C to treat scurvy.[1] Scurvy was a major cause of mortality for early sailors. In 1497, Vasco Da Gama lost 100 out of 160 crew members to scurvy sailing around the Cape of Good Hope. A dietary connection was suspected, and in 1601, British Navy Captain James Lancaster was in command of 4 ships traveling from England to India when he performed a clinical trial to test whether lemon juice could reduce the incidence of scurvy. He required sailors to take 3 teaspoons of lemon juice daily on 1 ship, while sailors on the other 3 ships served as the control group. The results were astonishing; while 110 of 278 (40%) sailors died in the control group, there were no deaths in the experimental group. Despite this impressive result, the intervention was not widely adopted. In fact, in 1747, British Navy Physician James Lind repeated the study with similar results. It was not until 1865 that the British Navy finally adopted the innovation,

264 years after Captain Lancaster's successful clinical trial!

Has the situation changed today? Remarkably, a recent study found that it now takes an average of 17 years for new knowledge generated in randomized clinical trials in the United States to be implemented in clinical practice, and even then, implementation is highly non-uniform.[2] Technology diffusion is even slower in developing countries, which frequently do not have the capacity to carry out medical research, and must instead import new technology developed in other settings.[3]

Let's examine the pace at which adoption of new technologies proceeds. If we graph the fraction of a target population who has adopted a new technology over time, we find that the curve frequently has an S-shape (Figure 14.2). Initially, diffusion is slow. As more of the population adopts the innovation, the speed of diffusion increases. Often, we find that there is a tipping point, when between 15% - 20% of the population have adopted an innovation, its spread becomes difficult to stop. At some point, the market is nearly saturated and diffusion again slows. The shape of this curve has been found to be remarkably similar for many different types of innovations.

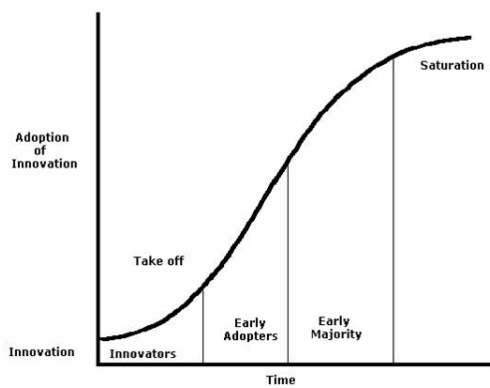


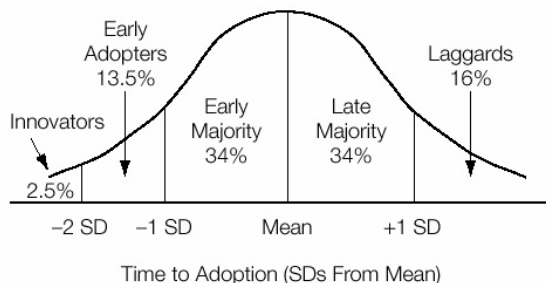
Figure 14.2: Innovation adoption curve.

Source: [6].

It is interesting to think about how the people responsible for innovations and their adoption interact during this process. The group of people who most rapidly adopt new technologies are the innovators who develop these new technologies (Figure 14.3). Innovators are willing to take risks to develop new technologies; they are often perceived as risk takers or mavericks, who may be overly invested in the success of their own innovation. As a result, they may be viewed as incautious and are frequently socially disconnected. Next to adopt a new technology are the early adopters; this group of people is usually involved in testing and comparing the efficacy of several new interventions in order to determine which is most effective. Early adopters are viewed as well connected, social opinion leaders; their actions are watched by the communities in which they practice. The early majority generally follows the lead of early adopters to accept new innovations. They rely on the conclusions of people they know before deciding to test a new change. The late majority wait to see local proof that a new intervention is effective before adopting it. Finally, the most conservative group, sometimes called laggards, wait to adopt a new innovation until it has become the status quo or standard of care.

Figure 14.3: Characteristics of people who adopt change.

Source: [5].



Let's examine a case study of the diffusion of a relatively

ISOS Village Presentation: June 29, 2007**Christina****Lesotho**

I have to admit that I found myself the night before last feeling a bit nervous about rolling out the activities and interacting on an educational level with the students. Although I have worked with youth before and have had similar experiences with refugees from various African countries, I was still unsure of how the students would respond to our teaching styles and activities. I now know what some teachers describe as the butterflies in their stomach the night before their very first day of teaching.

After setting up our projector in the community hall, students began trickling in, one by one. We introduced ourselves, and again I was embarrassed by my lack of ability to pronounce their names. The initial ice was broken when they asked if I had music on my computer. They requested hip-hop or R&B and knew a few Usher songs and a Will Smith song I played.

We kicked off the first day with an ice breaker game in which the children split into two groups and lined up behind a blanket. When the blanket dropped, the students had to shout the name of their classmate on the other side of the blanket as fast as possible. It was so funny to watch their reactions as the blanket dropped and to keep them from peeking underneath the blanket.

I had my moment as the strict teacher and did my share of nagging. It turns out the concept of a pre-test is not common around here and even when we told them they could leave their names off the test, we had the toughest time convincing them that the pre-test we were giving out was only for our own knowledge—that it would never be graded or shown to their teachers. They were whispering to each other and trying to share answers left and right. I definitely did my part to stand over the mischievous ones, pace back and forth to scare them a bit, and laughed inside as their little eyes turned quickly away from their neighbors' papers as they looked up and saw me coming by.

I am really not sure how much they liked the powerpoint style of presentation, but I think it was something different and kept their attention fairly well. They were happy to get up in between slides and play the snowball game. We had them write down a question they were curious about relating to HIV, science, health, life in general and keep it to themselves. They then split up into two teams on opposite sides of the room and we told them to crumple up the papers and begin throwing them at the opposing team. It was absolute mayhem and turned out even better than we imagined.

There was a question asking what love is. This age group was 12 years old and above, and this question puzzled me at first. Remembering that many of these children are orphans and know only the love of a house mother who takes care of 9 others, I took back a bit of my confusion and began thinking of the millions of orphaned children who most likely have never knowm



unconditional love. Nothing pains me more than thinking of the plight of orphaned children, and every day that I walk through SOS, I am so thankful for the care and opportunities available to these children. I only wish this experience could be multiplied for so many others.

We prepared this morning for our afternoon at SOS again by finding appropriate images to describe the male and female reproductive systems since we found ourselves motioning around our own bodies most of the time yesterday. It's always such a pleasure to walk into the SOS Village because there are always children walking around who are so excited to see us and greet us with the warmest smiles. I want to get to know every child I pass, and I wish I had time to spend with each one of them.

Today's lesson and activities also went well, and the children are gaining so much knowledge that I think the questions I asked during some of the games were too easy. No one really got a kick out of the Twister board we brought, though, and they were all too shy to be the ones to play on the board. Overall, we found the boys to be more open and curious than the girls. The girls had questions and would whisper them to their most vocal friend, but the questions were few and I would really like the opportunity to sit in a smaller group setting with the girls. They are all sweet and welcoming, and seem to want speak with us on a more intimate level.

After the presentation and games, we got to run around with the younger ones a bit and catch them on the playground. Again, they loved posing for pictures and seeing themselves when the picture came up on the digital camera. I cannot explain the way the children look at me, but maybe a few of the shots

can capture their spirit, personality, and love of life.



new technology—that of laparoscopic cholecystectomy—or removal of the gall bladder using fiber optic guided surgery. This procedure was one of the first minimally invasive surgical procedures to be developed and the story of its adoption illustrates many of the concepts we have just introduced.

The gall bladder (**Figure 14.4**) acts to store bile made by the liver. After you eat a meal, the gall bladder contracts, and secretes bile into a duct which empties into the small intestine. Bile provides an important aid in digestion. In some cases, liquid bile may precipitate into solid stones called gallstones. This is a relatively common occurrence, with nearly 1/5 of North Americans and ¼ of Europeans developing gallstones at some point in their lives. If gallstones block the bile duct, patients can experience severe abdominal discomfort and pain, heartburn, and indigestion.

Prior to 1990, gallstones were treated in an open surgical procedure to remove the gall bladder. At this time, surgical removal of the gall bladder was the most common non-obstetric surgical procedure in many countries. While effective and relatively safe (mortality rate 0.3-1.5%), this procedure required that patients stay in the hospital for about a week, and most lost 30 days of time from work.

Laparoscopic cholecystectomy was a new procedure developed in the 1980s which allowed for shorter hospitalization, more rapid recovery, an earlier return to work, and significant financial savings. In this procedure (**Figure 14.5**), the patient receives general anesthesia, but only a small incision is made at the navel enabling a thin tube carrying a video camera to be inserted. The surgeon then fills the abdomen with carbon dioxide gas. Two needle-like instruments are inserted into the space created by filling the abdomen with gas. These instruments can be seen on the video monitor and serve as tiny hands, used to pick up the gallbladder and to manipulate the intestines. Using such instruments, the surgeon clips the gallbladder artery and bile duct, and safely dissects and removes the gallbladder and gallstones. The gallbladder is then teased out of the tiny navel incision. The entire procedure takes only 30 to 60 minutes. It requires only three puncture wounds which do not need sutures. The procedure does not result in a scar; the three puncture wounds leave very slight blemishes and the

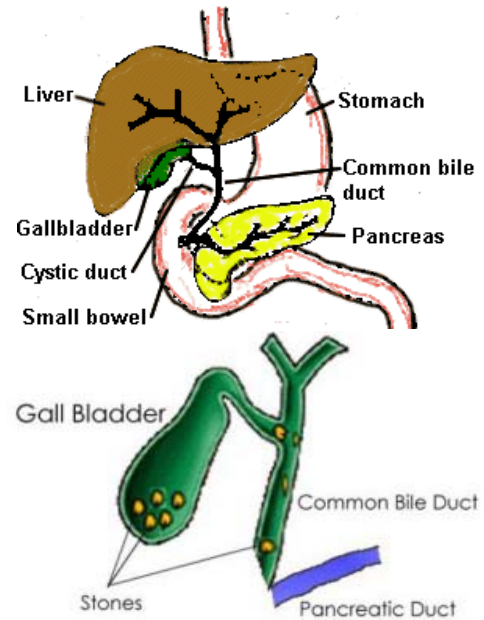


Figure 14.4: The gall bladder is located just beneath the liver. It stores bile made in the liver. Upon contraction, bile is secreted into the small intestine to aid in digestion. When gall stones form in the gall bladder, they can block the outflow of bile, leading to acute inflammation which must be treated surgically.

<http://gensurg.co.uk/images/Biliary%20anatomy%20-%20hsk.jpg>
http://www.thaiclinic.com/images/biliary_anatomy.gif
<http://www.qualitysurgical.com/gblad.jpg>

Figure 14.5: In laparoscopic cholecystectomy, the abdomen is filled with CO₂ gas to create a space for surgery. A camera inserted through the navel is used to visualize internal organs and small surgical instruments used to manipulate tissues (left). Arteries and ducts leading to the gall bladder are clipped so that gall bladder can be removed (center). When resected, the gall bladder is removed through the incision in the navel (right).

<http://www.lapsurgery.com/gallblad.jpg>



Technology Diffusion

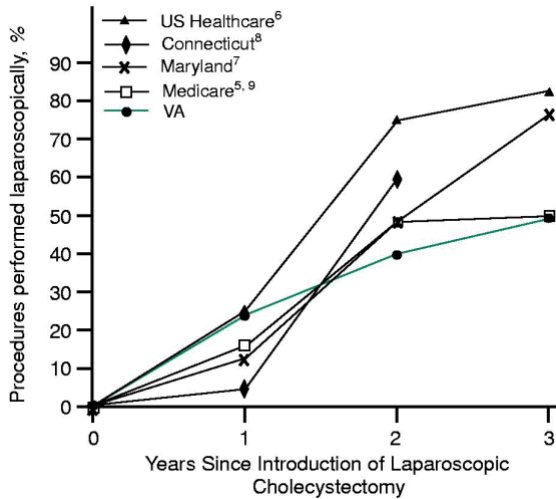


Figure 14.6: Rate of diffusion of laparoscopic cholecystectomy [4].

<http://www.acponline.org/journals/ecp/marapr99/diffus.pdf>



Figure 14.7: Kurt Semm (1927-2003), innovator responsible for the era of laparoscopic surgery.

navel incision is barely visible.

Laparoscopic cholecystectomy has been called the most significant major surgical advance of the 1980s. This procedure was the forerunner of a new era of minimally invasive surgery. The benefits of the less invasive procedure include the ease of recovery, since there is no incision pain as occurs with standard abdominal surgery. Following laparoscopic cholecystectomy, about 90% of patients can go home the same day. Within several days, they can resume normal activities. The rate of complications for the laparoscopic procedure is about the same as for standard gallbladder surgery. Complications include nausea and vomiting which may occur after the surgery. In addition, injury to the bile ducts, blood vessels, or intestine can occur, requiring corrective surgery. In about 5 to 10% of cases, the gallbladder cannot be safely removed by laparoscopy. In these cases, standard open abdominal surgery is then immediately performed.

Let's examine the rate of diffusion for this new surgery. In fact, no technique in modern times has become so popular as rapidly as laparoscopic cholecystectomy. Its diffusion in health care is unprecedented. The technique was introduced in 1989; **Figure 14.6** shows the percentage of gall bladder removal surgeries which were performed laparoscopically in the subsequent years. By 1992, laparoscopic cholecystectomy accounted for 50% of all cholecystectomies in Medicare populations and 75% to 80% of all cholecystectomies in younger populations. Today, the laparoscopic procedure has rapidly become the most widely used treatment for gallstone disease. The introduction of laparoscopic cholecystectomy is associated with a 22% decrease in the operative mortality rate for cholecystectomy. In fact, the introduction of this new, minimally invasive procedure led to a substantial increase in the overall rate of cholecystectomy, as patients who were previously not good candidates for an open surgery could tolerate the risks of the minimally invasive procedure.

Given the success and rapid diffusion of this procedure, how was its innovator viewed? The man largely responsible for the innovations that enabled laparoscopic surgery is Kurt Semm (**Figure 14.7**). Semm, a gynecologist, contributed more than 80 medical device inventions during his life. They included the electronic insufflator, the use of thermocoagulation, the loop ligator, and methods to suture structures during laparoscopy.

Semm's brother and father owned a medical instrument company which rapidly produced instruments for him that he could test. His ability to rapidly prototype and test new instruments enabled Semm to attempt to perform increasingly complex procedures endoscopically. Semm developed minimally invasive

The Tools of Laparoscopic Surgery:



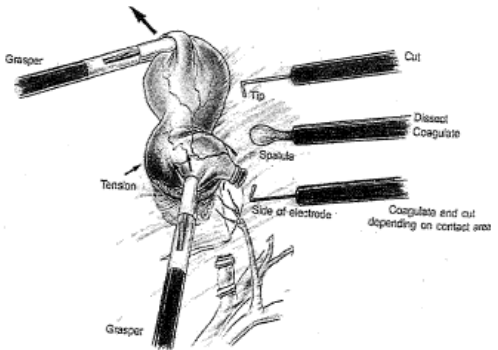
Insufflator



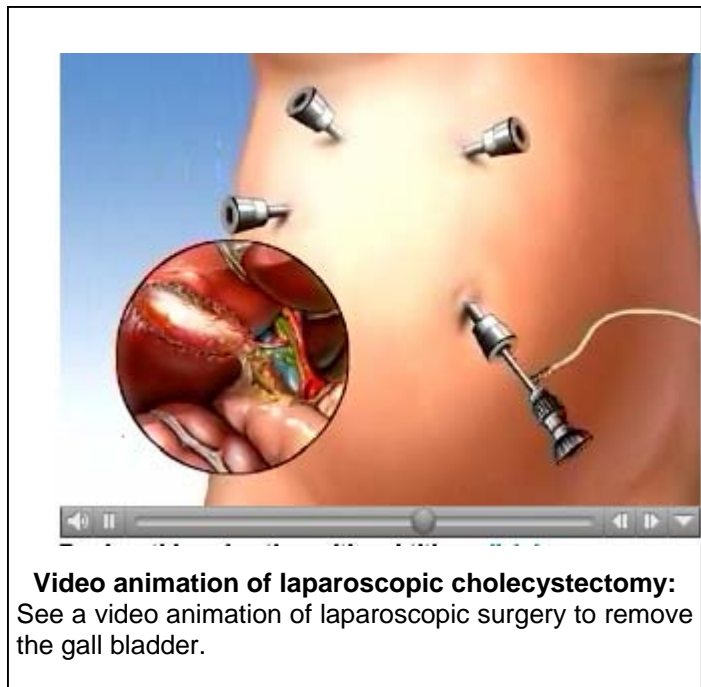
Trocar



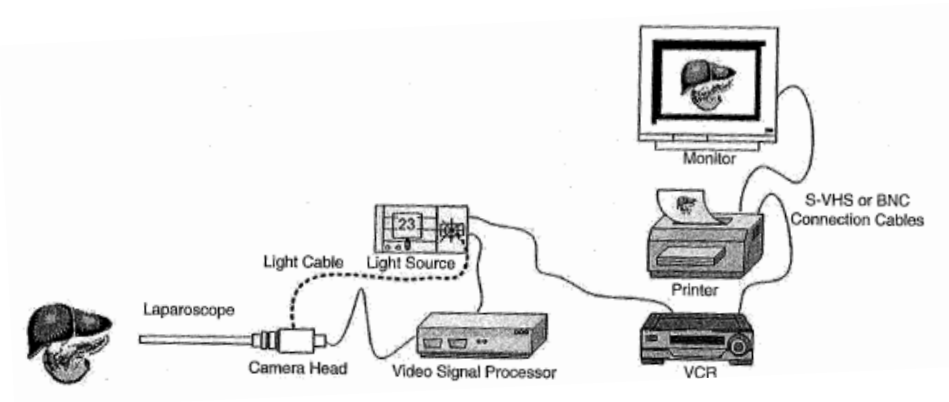
Camera



Clips and forceps used in laparoscopic procedures.



Video animation of laparoscopic cholecystectomy:
See a video animation of laparoscopic surgery to remove the gall bladder.



Laparoscope with illuminator and camera system

approaches to perform surgical procedures in both the areas of gynecology and general surgery.

In 1985, Semm's techniques were used to perform the world's first laparoscopic appendectomy. At the time, the laparoscopic approach was said to reduce the problem of adhesions which frequently formed following open surgeries. How did Semm's peers react to these advances? Semm was said to have gone "absolutely crazy." He was asked to undergo a brain scan by his colleagues. His lectures were initially greeted with laughter and derision. His techniques were initially viewed as too expensive and too dangerous. Further, colleagues said that Semm exaggerated the problems of adhesions associated with open surgeries. At the time, most surgeons saw no reason to change a well established working method into a complex technical manner. Because he was a gynecologist, he was accused of having "surgeon envy", and was accused of trying to enter into general surgery to bolster his "operation ego".

Later, reflecting back Semm said, "Both surgeons and gynecologists were angry with me. All my initial attempts to publish on laparoscopic appendectomy were refused with the comment that such nonsense does not and will never belong to general surgery." As we know today, Semm displayed an ability to push his ideas through despite skepticism and suspicion. In fact, without Semm, the laparoscopic revolution may have been postponed by many years.

Can we use our growing knowledge about the determinants of technology diffusion, to speed the adoption of new health technologies which are proven to be safe and effective? A number of strategies have been suggested [1], including:

1. Find sound innovations: In the next chapter, we will consider how medical research is funded, and how this impacts the development and diffusion of new innovations.
2. Find and support innovators: As the story of Kurt Semm indicates, innovators who lead major changes often come from outside the field, and their contributions are not always initially appreciated.
3. Invest in early adopters: Finding leaders within the field to champion a new change can decrease the resistance to that change. The speed of diffusion can be increased by providing avenues to connect innovators and early adopters.
4. Make the activity of early adopters more visible: In making decisions about whether to adopt new innovations, the early majority looks to the activity of early adopters. Providing formal opportunities for these groups to interact can help increase the speed of diffusion.

5. Trust and enable reinventions: Often early adopters and the early majority adopt new innovations only in part, adapting them to make them most effective in their local setting. Innovators are sometimes resistant to these changes, believing that they are an indication of resistance. Supporting effective local reinvention can speed diffusion.
6. Create room for change: Adoption of new innovations requires energy; if people are not given time and resources to support this, new innovations cannot diffuse.
7. Lead by example: Adoption of new innovations requires change at all levels in a system; leaders themselves must be open to change if diffusion is to occur.

New innovations arise and are proven effective through a combination of basic science research, engineering design and clinical trials. In the next chapter, we will consider how health-related research is funded and regulated. We will see that the ways in which research is financed and regulated have an enormous impact on both innovation and the diffusion of innovation. This provides a unique opportunity to modify funding and regulatory policies to implement and reinforce the seven lessons considered above.

Chapter 14 Homework

1. Contrast the rate of diffusion of the following two innovations: vitamin C to prevent scurvy in sailors, and laparoscopic cholecystectomy.
2. How are innovators, such as Kurt Semm, often viewed by others when introducing new technologies for health problems that replace treatments considered by leaders in the field as already successful?
3. Why does it take so long for a promising new technology to reach the market in the United States? What hurdles must researchers overcome to deliver an innovation that is marketable?

References

- [1] Berwick DM. Disseminating innovations in health care. *Jama*. 2003 Apr 16;289(15):1969-75.
- [2] Balas E, Boren S. Managing clinical knowledge for health care improvement. In: Bommel J, McCray A, eds. *Yearbook of Medical Informatics*. Stuttgart, Germany: Schattauer 2000.
- [3] Papageorgiou C, Savvides A, Zachariadis M. International Medical Technology Diffusion. *Journal of International Economics*. 2007;72(2):409-27.
- [4] Ferreira MR, Bennett RL, Gilman SC, Mathewson S, Bennett CL. Diffusion of laparoscopic cholecystectomy in the Veterans Affairs health care system, 1991-1995. *Eff Clin Pract*. 1999 Mar-Apr;2(2):49-55.
- [5] Rogers EM. *Diffusion of Innovations*. 4th ed. New York, NY: Free Press; 1995.
- [6] Rogers, E. *Diffusion of Innovations*. 3rd ed. New York, NY: Free Press, 1983.