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Medical Technology: Contexts and Content in Science and Technology

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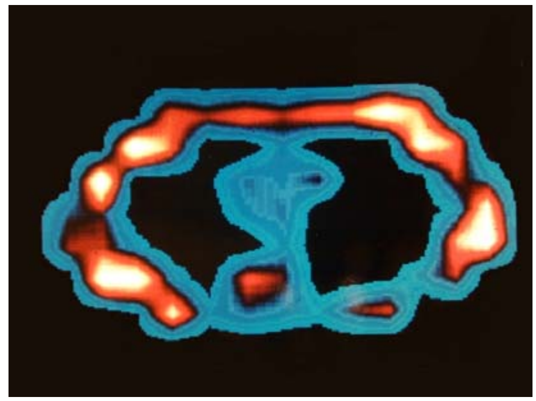
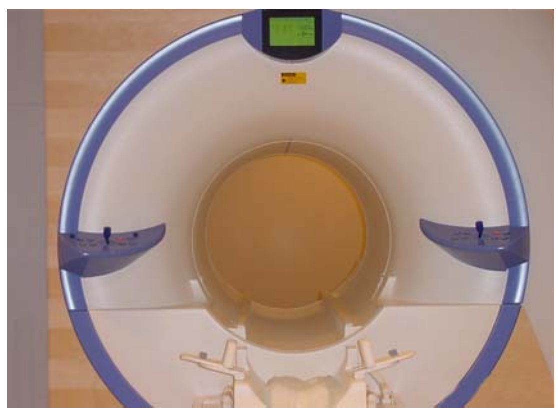
Medical Technology





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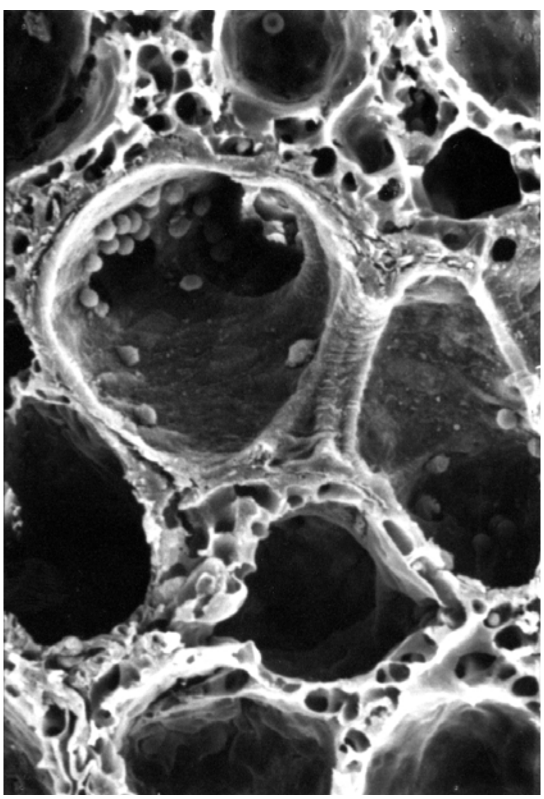

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On the cover:

- The first magnetic resonance imaging (MRI) scans of a live human body showing a cross section of a live human chest. Courtesy FONAR Corporation.
- MRI chamber courtesy of Harmony Imaging Center, Poudre Valley Hospital.
- Microscope courtesy of Ken Goldberg, UC Berkeley.
- Syringe courtesy of budgetstockphoto.com.

Interleaf:

- Skin fold test courtesy of Colorado State University Human Performance Clinical/Research Laboratory.
- Ovariohysterectomy surgery being performed on a dog. Courtesy of C. Lasure-Hearne, Cedar Valley College of Veterinary Technology.
- Blood vessel under magnification. Courtesy Michigan State University.

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Courtesy of the Rocky Mountain Magnetic Resonance Center at Colorado State

Medical technician viewing an MRI image scan.

Foreword

Medical technology in some form has been part of medical practice since the early days in the history of medicine. This well-written book is the first concerted effort to capture the essence of medical technology and present it in a form that will make the study of medical technology a viable content area of study for grades 3-12.

Medical Technology: Contexts and Content in Science and Technology Education is a medical technology primer. It is designed to assist teachers and curriculum designers in developing medical technology content in schools. The authors use a clearly organized approach to guide us through the significant historical events of the field, including major technological breakthroughs, and the ethical decisions that physicians and others made as they established the foundation for today's world of medical technology.

Any study of medical technology would be incomplete were it to attend only to the physical characteristics of the artifacts themselves. This book pays careful attention throughout to the social context and conceptual framework within which each technology was created and used. It gives specific guidance on content background and it offers a rationale and structure in which to conceptualize medical technology. The authors use vignettes throughout, which will help to bring the field of medical technology to life for many students.

Increasingly, educators have been challenged by the rapid development of new technologies, and the challenges brought forth by the development of new medical technologies are no exception. Educators in science, technology, mathematics, and applied engineering will find information in this primer with direct applications for the school curriculum.

Now, more than at any time in the history of formal education in America, educators are challenged to bring the field of medical technology to life in the classroom. I join my colleagues in congratulating Michael A. De Miranda A. Mark Doggett, and Jane T. Evans on writing an excellent medical technology primer. The world of medicine is becoming an ever-more important part of daily life. Everyone needs to understand the essentials of health care, and to understand health care has come to include understanding the essentials of medical technology. In the years to come we will surely see more and more new medical technology. This volume could help students and educators become more knowledgeable consumers and critics of health care during the remainder of the 21st century.

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Preface

Medical Technology: Contexts and Content in Science and Technology is one of a series of documents envisioned to assist educators in improving and strengthening students' knowledge in a specific area of science and technology. Its purpose is to build a basic understanding of medical technology using historical perspective, conceptual framework, and educational vignettes. It was designed for use by educators who have an interest in introducing medical technology as part of a science, technology, mathematics, or applied engineering curriculum. The *Standards for Technological Literacy* (STL) published by the International Technology Education Association (ITEA) described twenty content standards in technology for grades K-12. This primer specifically addresses Standard 14 of that document: students will develop an understanding of, and be able to select and use medical technologies. The American Association for the Advancement of Science in *Benchmarks for Science Literacy* included the study of health science for K-12 curriculum as Benchmark 8F. This primer is congruent with that benchmark.

In this document, the use of the term medical technology is expansive and encompasses more than the field of clinical laboratory medicine as defined by the medical community. Our use of the term medical technology is the application of procedures, information, and devices to develop highly sophisticated solutions to medical problems or issues such as the prevention of disease or the promotion and monitoring of good health. Medical technology is also commonly confused with biomedical technology; however, there is a distinct difference. Biomedical technology applies principles of biological and physiological sciences. Biomedical technology employs living organisms (or parts of organisms) such as human tissue, DNA, or pharmaceutical products for medical use.

The primer is organized into four sections. Section I assists the reader in understanding the historical context of medical technology as it evolved over time and some of the technological breakthroughs that were instrumental in shaping its current state. This section also highlights and describes some of the social contexts and ethical issues raised by medical technology. The section concludes with an introduction to the nature of medical technology and uses a guided dialogue to describe the attributes and character of the technology. Section II presents the conceptual framework for the study of medical technology and gives examples that educators can use to develop educational exercises. Section III provides educators with grade-specific concepts, vignettes, and ideas for developing medical technology curriculum and lesson plans. Section IV offers a Taxonomy, Framework and Context for the Study of Medical Technology Finally, Section V offers references and additional resources for professional development in the study of medical technology.

This document was reviewed by physicians, nurses, technicians, and medical practitioners for accuracy, relevance and clarity. Input was also gathered from scientists, engineers, mathematicians, and science and technology educators. Please read the document, study it, and join with other education professionals in developing a greater understanding of this exciting and rapidly-changing field. The study of medical technology is not an independent discipline, having a set of technologies of its own, but borrows and applies principles from many other sciences and technologies. For this reason, medical technology is a growing field of interest and will continue to be a viable subject for the generations of the future.

Introduction

One of our challenges was to produce a document of relevance for educational practitioners in science and technology that could help them conceptualize and gain a basic understanding of the medical technology field. Detailed lesson plans and classroom activities are not the focus of this document. This document is designed to aid the teacher in understanding and applying the principles and nature of medical technology in the design of curriculum and instruction. Thus, one of the features of this text is that it does not tell practitioners exactly what to do when teaching a unit or an integrated lesson related to medical technology; it provides a framework.

The reader of this text should be cautioned that medical technology does not fit neatly into the traditional content classifications generally used by teachers of science and technology. Because of the nature of medical technology, it cannot be put into a box—it squirts out and redefines the traditional field of technological study. Because it does not fit in any one technology paradigm, it may, on some level, characterize the future of technology: a cross-disciplinary field with interfaces between human, technological, and scientific systems.

Taxonomy for a Complex Technology

Because of medical technology's cross-disciplinary nature, it is valuable to introduce the reader to taxonomy. Medical technology applies energy forms to body systems. Energy forms are the physical forms of energy that exist in the universe, i.e., magnetic energy, thermal energy, electrical energy, chemical energy, etc. Medical technology applies energy forms (generally using devices such as x-ray machines, electrocardiographs, or precision lasers) to diagnose and treat various parts of the human body or body systems. Body systems regulate the operation of the human condition by controlling functions like circulation, digestion, or respiration. However, medical technology literacy requires more than learning about energy forms and body systems.

Medical technologists must also know about the appropriate procedures and devices for the diagnostic/therapeutic application of the energy forms to body systems. Therefore, knowledge, procedures, and devices simultaneously define the application of medical technology. Consequently, medical technology requires a foundation in both science and technology. In addition to science and technology, the basis for medical technology resides within the context of the social, political, and cultural world. Thus, medical technology is the application of energy forms to diagnose and treat body systems using knowledge, procedures, and devices within the context of both science and technology in society. A conceptual Venn diagram on the next page characterizes this perspective.

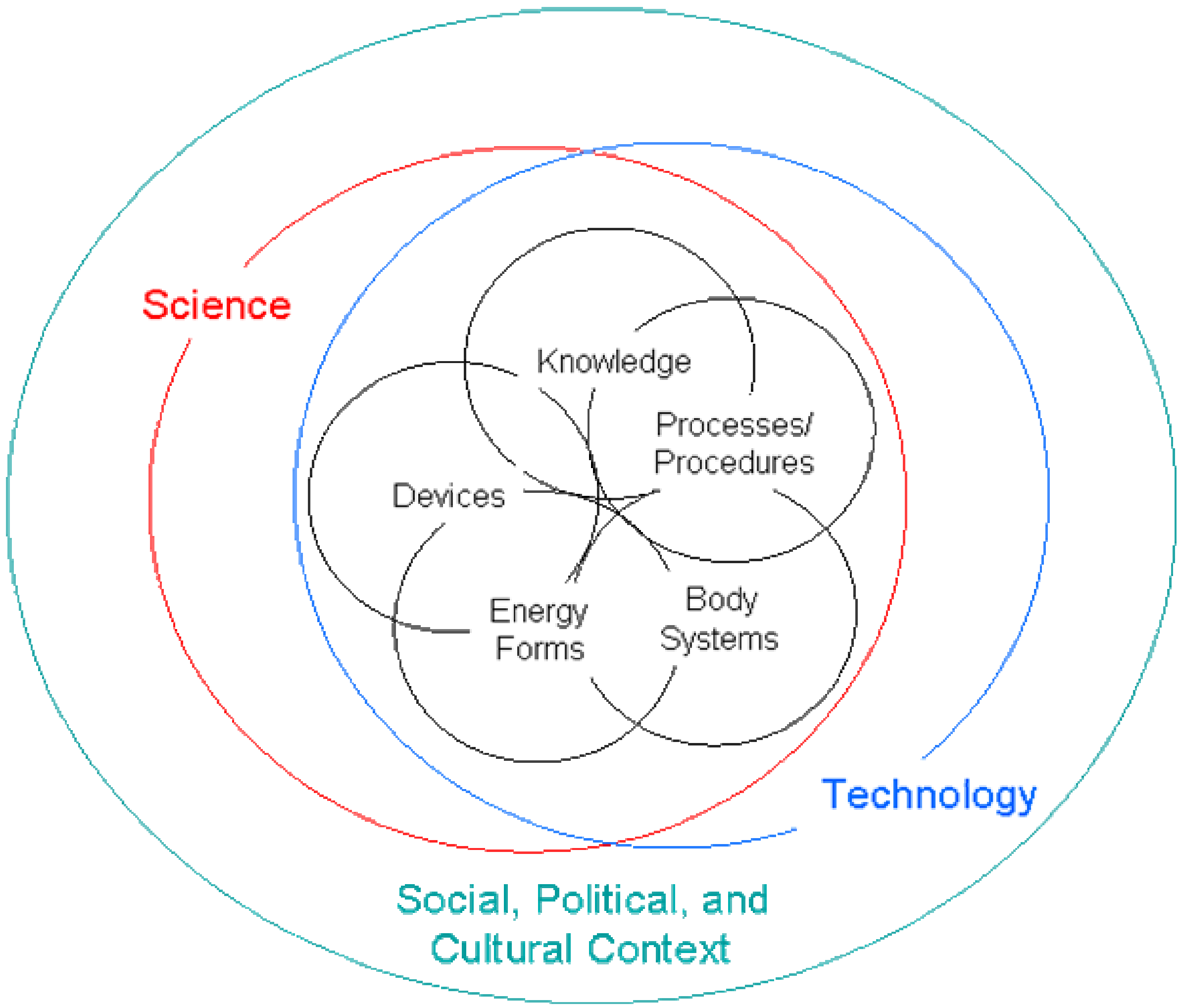


Figure A. Interaction of Science and Technology with Regard to Medical Technology

Key Elements in Context and Content

To assist the teacher practitioner, this document was designed to be as user-friendly as possible. The important paragraphs to read have been highlighted with the key icon shown below.

The reader should pay careful attention to paragraphs identified with this icon as they indicate a key point, core concept, or item of importance that defines and conceptualizes the content or context of medical technology. This is not to say that the reader will find the unmarked paragraphs of little use, but that the authors understood the pace of busy lives that may require a quicker read of the major topical areas.

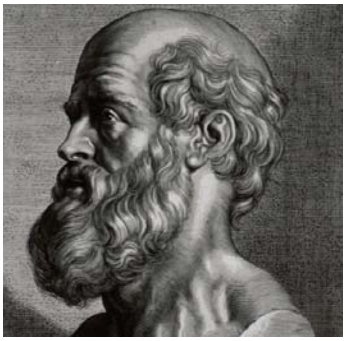
Section I: Medical Technology in Context

What will this section cover?
Historical background
Social and ethical implications of medical technology
Introduction to medical technology

What will this section help me understand and be able to do?
Identify key medical technology breakthroughs
Describe the transition from general medical practice to specialization
Explain how medical technology has complicated perspectives of life and death
Develop an understanding for the meaning, nature, and characteristics of medical technology

The History and Impact of Medical Technology

In the early beginnings of humankind, disease was viewed with mystery and was a common occurrence that claimed many lives (Porter, 1996). It was thought that disease was caused by the negative interaction between environmental elements and body fluids (Reiser & Anbar, 1984). Poor health was considered a physical, social, or personal deficiency within the patient or the environment in which the patient lived. The four humors as described by Hippocrates (460-377 B.C) and Galen (131-201 A.D.) were an attempt to qualitatively measure a deficiency or excess of bodily fluids (i.e., blood, phlegm, yellow bile, and black bile) with respect to the changing seasons. Hippocrates and Galen were the first documented Western physicians to actively engage in a rudimentary science of healing designed to increase the quality of life for their patients. Medical technology evolved slowly in response to the high mortality rates associated with diseases (e.g., black plague) that in some cases caused the death of millions. Medicine and medical technology has become the antidote for illnesses and diseases that formerly resulted in the destruction of entire societies.


Courtesy National Library of Medicine

Hippocrates


Courtesy National Library of Medicine

Galen

Courtesy of National Library of Medicine

The operating room at Brinkley Hospital, circa 1921

Evolution of Medical Technology

Early practitioners of medicine relied primarily on the patient's descriptions of symptoms and their personal observations. They rarely examined the patient's physical body. Furthermore, emerging medical universities in 13th century Europe emphasized a theoretical and philosophical approach that discouraged medical students from placing their hands on the patient while learning the practice of medicine. This began to change as many physicians started to realize that medical texts first published in the 11th century and the general physician practices of the time had many errors. By the 18th century, doctors began to increasingly use manual (or mechanical) techniques to diagnose patients and cadaver dissection became more accepted as a medical practice (Reiser, 1978). While dissection of human cadavers and a physician's touch were extremely helpful in providing a more objective and accurate treatment, most of the general population during this period was reluctant to allow any doctor to physically examine them.

It was not until the 19th century that physicians increasingly used machines for diagnosis or therapeutics. Hutchinson's device for measuring the vital capacity of the lungs was one of the first technologies developed to numerically measure an essential body function. Another early device was Herisson's sphygmomanometer for blood pressure measurement. Chemistry also began to play an important role and was increasingly used in the 18th and 19th centuries to diagnose aliments such as diabetes, anemia, diphtheria, and syphilis (Reiser, 1978). Medicine slowly changed from the use of subjective evidence provided by the patient to objective evidence obtained by mechanical and chemical technology devices.

Courtesy of the National Library of Medicine

Surgery in the Sixteenth Century

From General Practice to Specialization

Medicine in the early 19th century was typically decentralized, rural, and consisted of general practitioners. Medical technology stimulated the growth of medical specialists in the United States. By the 1880s, the number of specialist publications in medicine was growing at a faster rate than those of generalist publications. The number of medical specialties recognized by the International Medical Congress increased from eight in 1875 to an estimate of 34 in 1915 (Reiser, 1978). In 1930, only one out of four practitioners was a medical specialist. By 1980, more than four out of five doctors were specialists (Reiser & Anbar, 1984).

There were many factors that drove medical specialization. First, patient populations started to become concentrated in urban centers and the large numbers of patients created economic incentives for doctors to relocate to those areas. Second, general practice physicians sought to escape the irregular hours of practice and specialization seemed to hold more prestige. In addition, there were no professional or administrative barriers that prevented specialists from competing with the generalists for patients (Reiser, 1978). Third, the nature of medicine changed such that general practitioners could no longer keep up with the amount of knowledge required to make accurate diagnostic or treatment assessments. Fourth, the machinery and equipment used in medical practice became quite complex requiring specialized technical expertise and support.

Courtesy Museum of Health Care at Kingston

Fleischer stethoscope 1923-1963

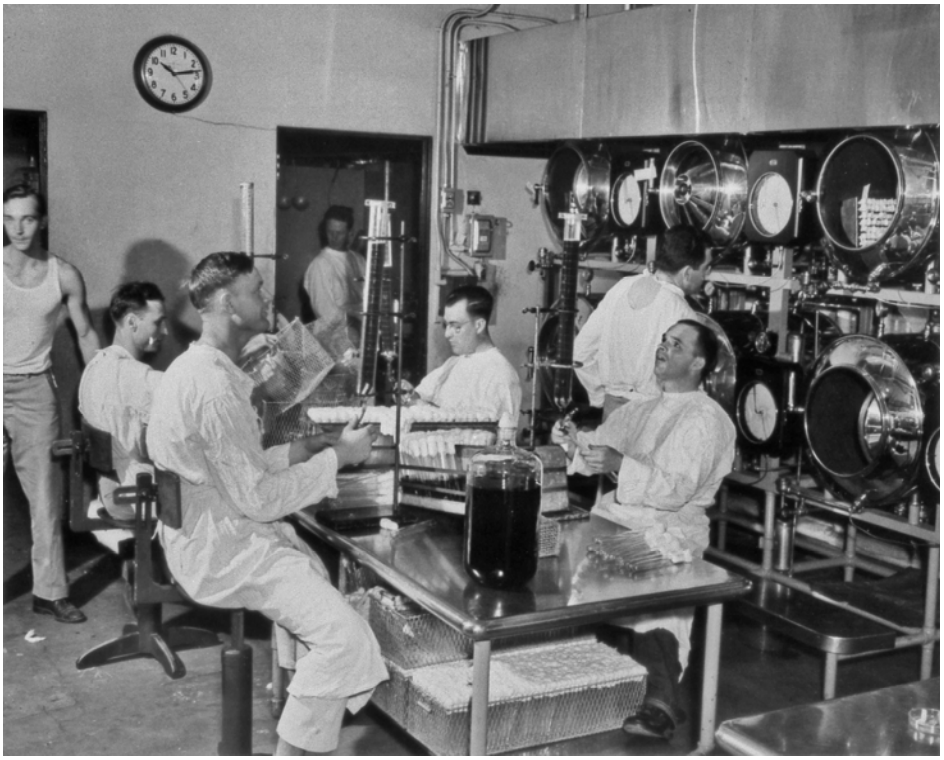
As more doctors became specialists, the need arose for more cooperative arrangements since no single physician possessed all of the special knowledge required. The result was an increase in the number of physicians associated with private medical groups and hospitals began to function as an integrator of medical technology. Medical services became organized around cooperative practice arrangements. An unfortunate by-product of this organization was a decreasing level of local medical services in many rural areas (Reiser, 1978). Specialization forced physicians to become centrally located and increasingly cooperative. Hence, the hospital became the central locus for medical care (Reiser & Anbar, 1984). Medical technology and specialization also increased the amount of data required to diagnose and treat a patient. Thus, the medical record became the central focal point for retaining patient information and created the need for information technology to organize and store voluminous amounts of data. This, in turn, created the need for medical technicians and data specialists such that by 1969, 80 percent of those employed as medical professionals were non-physicians (Reiser, 1978).

This exponential growth in medical technology and data created the need for more technicians, of all kinds, to test and to manage medical data. Medical technology also created educational needs. Medical technicians needed education to become proficient in the use of technology to help treat and diagnose illness. Patients needed education when confronted with the often confusing decisions regarding the tests and procedures performed for their health and well-being.

Critics of specialization assert that technology has created less face-to-face contact between the patient and an actual doctor. Physicians have become more dependent on the use of technology for diagnosis and treatment. Technical equipment and the expertise of technicians are now being relied on for many medical decisions that were formerly doctors' opinions. Technology has taken the diagnostic assessments that used to be based on patient descriptions or doctor's examinations and transferred them to medical, chemical, or radiological laboratories. The result has been an increase in diagnostic accuracy at the expense of close doctor-patient relationships (Reiser & Anbar, 1984).

Technological Breakthroughs in Medical Technology

Some of the early breakthroughs in medical technology were the thermometer, stethoscope, microscope, ophthalmoscope, laryngoscope, and x-ray. These devices allowed the physician to hear and see parts of the body that had previously been observed only in cadavers. The device considered to be the first diagnostic medical



Courtesy of the National Library of Medicine

Medical laboratory, 1944

Courtesy Museum of Health Care at Kingston

Early Zeiss microscope

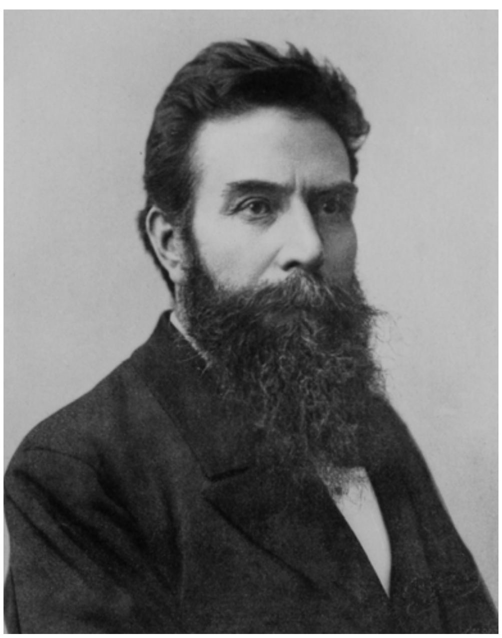
technology breakthrough was the stethoscope. Rene Läennec, a French physician familiar with acoustics, invented the stethoscope in 1816 by serendipity. The invention offered numerous solutions for acquiring information about the lungs and heartbeats of patients. However, skeptics initially challenged its merit and effectiveness. In spite of the initial opposition to its value, the stethoscope is still being used by medical professionals today (Reiser, 1978).

Magnifiers were invented in the 1st century, but microscopes were not used for medical purposes until the 1840s. This was due primarily to advances in lenses, better stains, and lower costs. Hermann von Helmholz, a German scientist, applied the principles of optics with the invention of the ophthalmoscope in 1850. This was the first visual technology to view the interior of the eye (Reiser, 1978).

Another technology was the invention of the laryngoscope invented by Manual Garcia in 1855. Garcia, a London singing teacher, placed a mirror in the back of the throat and another mirror to reflect sunlight into the mouth to observe the action of the throat and larynx. Two years later, Johann Czermak, a Polish professor of physics, replicated his experiment using artificial light (Reiser, 1978).

Forty years passed before the use of electricity resulted in the invention of the x-ray. Wilhelm Roentgen, a professor of physics in Bavaria, discovered by accident a radiation that could penetrate solid objects of low density. He also found that these phenomena could be viewed on a fluorescent screen and stored on photographic film. The invention of x-rays allowed doctors to view the inside of the body without surgery. In spite of the benefits of being able to produce images of the internal body structure, the x-ray was not an invention that diffused rapidly throughout the medical industry until World War II when it was widely used to diagnose pneumonia, pleurisy, tuberculosis, and assist doctors prior to surgery (Marks, 1993).

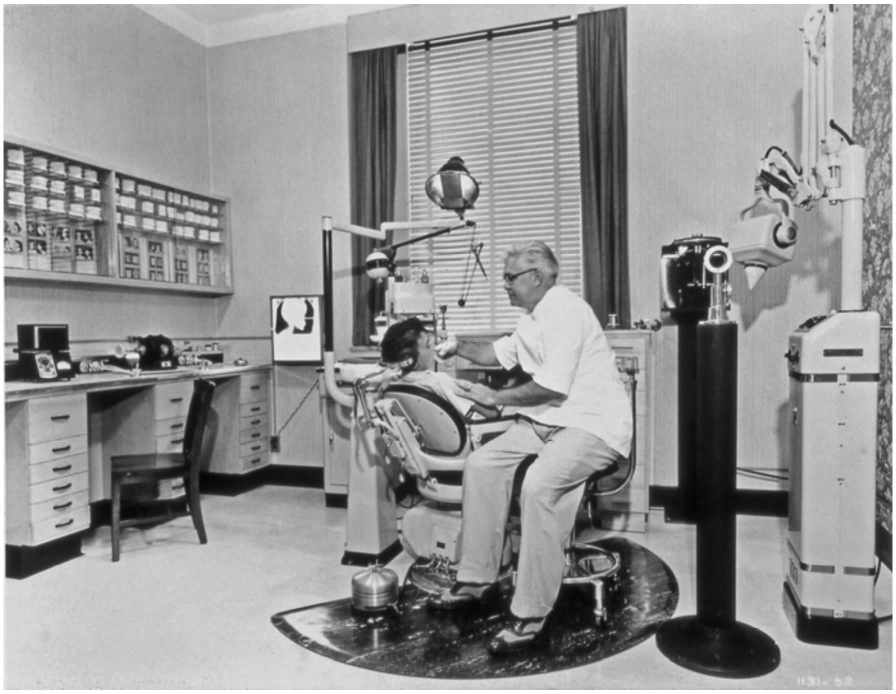
The development of chemical procedures in the 18th and 19th centuries significantly advanced the use of medical technology as a diagnostic tool for diabetes, kidney disease, anemia, diphtheria, and tuberculosis. As physicians came to realize that a chemical evaluation of disease required more specialized skills, they increasingly delegated this type of work to other experts or technicians. By the mid-1800s, many of these chemical experts organized their work by establishing laboratories for the analysis of medical specimens. By the mid-20th century, the use of technical laboratories for medical diagnostics had become so prevalent that the U.S. Congress placed them under the regulation of the Centers for Disease Control and Prevention (CDC) (Reiser, 1978).



Wilhelm Roentgen

Photos courtesy of the National Library of Medicine

First x-ray taken by Wilhelm Roentgen of Mrs. Roentgen's hand (note the wedding ring)



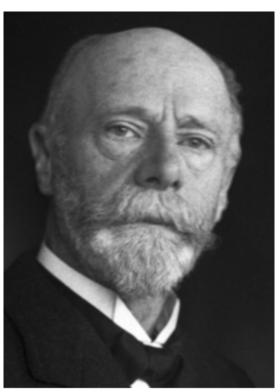
Courtesy of the National Library of Medicine

Dentist office, 1950s

Advances in Medical Technology Impact Medical Procedures

The rapidly expanding medical technologies available to the medical profession also advanced the development of complex surgical procedures. The Drinker respirator was introduced in 1927 and the first heart-lung bypass machine in 1939. In the 1940s, cardiac catheterization and angiography procedures were made possible through advances in material science. The use of a cannula threaded through an arm vein and into the heart with the injection of radiopaque dye for x-ray visualization made seeing the heart, lung vessels, and valves possible for the first time (Cruse, 1999; Howell, 1996).

Advances in medical technology accelerated in the early 20th century by improvements in basic science and the intense cross-fertilization of scientific and technological discoveries such as electrical measurement techniques, sensor development, nuclear medicine, and diagnostic ultrasound (Bennett, 1977). In 1903, William Einthoven devised the first electrocardiograph and measured the electrical changes that occurred during the beating of the heart. In the process, Einthoven initiated a new age for both cardiovascular medicine and electrical measurement techniques (Enderle, Blanchard & Bronzino, 2000; Snellen & Hollman, 1996).



© The Nobel Foundation

William Einthoven

In the early 20th century, Elizabeth Kenny, a trained army nurse from Australia, treated polio patients using hot packs and muscle manipulation. Her procedures, considered unconventional at the time, were initially rejected. After acceptance by the medical community, her techniques reduced residual polio paralysis from 85% to 15% in one year (Beckstrand, 1999). Kenny's principles of muscle rehabilitation became the pioneering foundation for modern physical therapy. She also invented a new stretcher device for transporting people in shock. Kenny’s life was later chronicled in a 1946 movie based upon her autobiography.

Courtesy of the National Library of Medicine

Computer data entry in the early 1960s

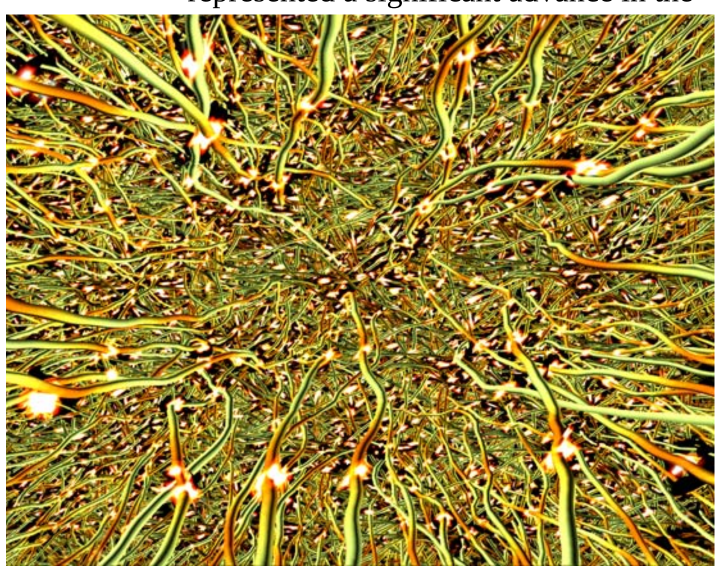
The development of new knowledge and procedures was so great that by the end of World War II, an unprecedented quantity of American engineers and scientists were directed to use their expertise to develop technology. During this time, extraordinary advances were made in electronics, material science, and thermodynamics, which were instrumental in the development of medical technology (Blume, 1992). The Mobile Army Surgical Hospitals (MASH) of the Korean War revolutionized medical surgical practice and gave rise to a new specialist, the Emergency Medical Technician (EMT).

As medical technology in the United States blossomed so did the prestige of American medicine. From 1900 to 1929, Nobel Prize winners in physiology or medicine generally came from Europe. In the period 1930 to 1939 prior to World War II, seven Americans were honored with Nobel Prizes. During the post-war period from 1945 to 1975, thirty-nine American life scientists were honored and from 1975-1995, thirty-one more were honored. Most of these efforts were made possible by the advanced medical technology available to clinical scientists (Levinovitz & Ringertz, 2001).

Dr. John H. Gibbon is credited with developing the first clinically successful heart-lung bypass machine after almost three decades of research. Using funding from IBM, the first successful use of the device was in 1953 on an 18-year-old girl with a heart defect. The first machine was massive, complicated, and difficult to manage. It also caused bleeding problems and consumed red blood cells. Today, modern heart-lung machines reduce patient bleeding through devices that preserve the surrounding blood supply and reduce the body temperature so the heart beats slower. Thus, a surgeon can protect the function of the heart and other vital organs during artificial circulation

The Science Technology Interaction and Medical Technology

Another technology applied to the medical field in the 1950s was the electron microscope. The electron microscope represented a significant advance in the



Courtesy of Greg Hood, John Burkardt, and Greg Foss; Pittsburgh Supercomputing Center

This image was derived from supercomputer animations showing a group of pyramidal brain cell axons as they simultaneously convey a burst of electrical activity from one cortical layer to another.

visualization of relatively small cells. Body scanners to detect tumors arose from the same science as well as the technology that ushered in the atomic age. Science and medical technologies tended to leapfrog past one another throughout recorded history. Thus, anyone seeking a causal relation between them is likely to find that technology is the cause and science the effect with the converse also holding true (Cruse, 1999).

In the 1970s, medical researchers adapted computers that advanced medical technology by performing complex calculations, keeping records via artificial intelligence, and controlling the instruments that often sustained life. The development of new medical imaging technologies such as tomography and magnetic resonance imaging (MRI) united with three-dimensional modeling was dependent on the information and computer technologies that were able to graphically represent body functions and condition (Bhatikar, Mahajan, & DeGroff, 2002).

Medical technologies provided prosthetic devices, such as artificial heart valves, artificial blood vessels, functional electromechanical limbs, and reconstructive skeletal joints. These innovations are the result of advances in science, technological imaging/design techniques, and material science (Lalan, Pomerantseva, & Vacanti, 2001). In recent years, the intersections of technology and medical science have impacted the practice of medicine in profound ways. Medical technology advances in the past 50 years has exceeded the advances during the previous 2000 years. In a culture steeped in science, it appears that the growth and use of medical technology will continue.

Courtesy FONAR Corporation

Drs. Raymond Damadian, Lawrence Minkoff, and Michael Goldsmith (left to right) in 1977 with the world's first magnetic resonance scanner that performed the first scan of a live human being.

Future Trends

The latest medical technologies now include robotic devices, keyhole surgery procedures, and genetic engineering created from knowledge about DNA molecules. Medical technology is now creating breakthroughs that may, once again, result in the decentralization of medicine through the telecommunication technology known as telemedicine. The importance of accuracy and medical record integrity has resulted in automated diagnostics and computerized data collection.

Yet, medical technology has not fulfilled the needs of many patients as indicated by an increased interest in holistic healing techniques, spiritual medicine, and mind-body treatment. Technology breakthroughs have proven their potential for improving the quality of life, but technology has also generated additional and valid concerns among general practitioners and patients.

Ethical Concerns

The technological and scientific innovations reviewed represent a small segment of the medical technologies that have influenced the progression and capabilities of medical care providers. The innovations in medical technology have endowed modern medical care providers with the ability to sustain and prolong life, repair damaged body parts, peer into the human body, cure and treat many diseases, and otherwise ameliorate a wide range of undesirable physical and mental conditions for which little could have been done in the recent past. However, to see only the benefits of medical technologies is to fail to see the whole picture. Along with these impressive advances and technological innovation come a number of difficult and often perplexing ethical issues with regard to quality of life and definitions of death (Beach & Morrison, 2002; Blake, 1988; Rajput & Bekes, 2002).

There is little doubt that the use of medical technologies has, in many instances, extended the possibility of life in individuals and increased the life expectancy of society as a whole. In the United States, at the time of this writing, the average life expectancy for males was 74.3 years and 76 years for females. This is in sharp contrast to the life expectancy of 47 years at the turn of the 20th century. While this increase cannot be attributed directly to medical technology, the modern technologies that promote health, early diagnosis, and make restorative surgical procedures possible have contributed significantly to theses gains over the past 100 years (Cooper, Stewart, Kahl, Brown, & Cordell, 2002).

Courtesy Poudre Valley Hospital

Telemedicine systems are used for home health monitoring. The patient (pictured on the left) is being checked remotely by the doctor (pictured on the right) for hand-flexibility following an operation for carpel-tunnel syndrome.

New Definitions of Life and Death

Medical technology has advanced the reevaluation of traditional definitions of life and death. Live fetuses can be removed from the womb many weeks prior to normal delivery and patients can be resuscitated after heart, lung, or brain failure. For example, premature births no longer constitute as great a threat as they did 30 years ago because of the artificial environments that medical technologies provide. Technology has not only helped individuals avoid death but also has been effective in adding more productive years to

Courtesy Poudre Valley Hospital

Ultrasound equipment is now used for a variety of purposes including scans of the carotid arteries located in the neck.

people's lives. Medical technologies such as pacemakers, artificial kidneys, insulin pumps, hearing aids, joint implants, and in-home health monitoring systems have been so successful that professionals responsible for the care of critically ill patients have been able to maintain patient "vital signs" for extensive periods of time. In the process however, serious ethical questions concerning the quality of life provided these patients have arisen.

Medical Codes of Conduct

In the practice of medicine, moral dilemmas are not new. They have been present throughout medical history. As a result, over the years there have been efforts to provide a set of guidelines for patient care and the ethical use of medical technologies. These efforts have resulted in the development of specific codes of professional conduct. For the medical profession and professionals who use medical technologies, the World Medical Association adopted a version of the Hippocratic Oath titled the Geneva Convention Code of Medical Ethics in 1949 (Rosenblatt, 2000). In 1999, the House of Delegates of the American Medical Association revised a set of Principles of Medical Ethics (World Medical Association, 1999). These codes take as their guiding principle the concepts of service to humankind and the respect for human life, and to do no harm nor malice.

While the established codes of conduct are useful in promoting the ethical treatment of patients and the conduct of the health service providers, the codes fail to provide answers to more difficult moral dilemmas involving the use and appropriation of medical technologies (Bronzino, 1992). For example, all of the fundamental responsibilities of a physician cannot be met at the same time. When a patient suffering from massive insult to the brain is kept alive by means of artificial respiration equipment and the equipment is needed elsewhere for the recovery of a surgical patient, it is not clear in the code of ethics guidelines how such decisions should be made.

Decision-Making

Consider the case of a patient who sustained a serious head injury in an automobile accident. When the emergency medical personnel and ambulance arrived at the accident scene, the patient was unconscious but still alive with a beating heart. After the victim was rushed to the emergency ward of a local hospital, the resident in charge verified the stability of the patient's vital signs of heartbeat and respiration during the initial examination. The physician ordered a

Courtesy of Harmony Imaging Center

Modern CT scanner

computerized tomography (CT) scan to indicate the extent of the head injury. The results of this technological procedure clearly showed extensive brain damage. What was the status of the patient? Was the patient still alive?

Alternatively, consider the events encountered during an open-heart surgery. During this procedure, the patient was placed on a heart bypass machine while the surgeon attempted to repair a damaged heart valve. As time passed on this long and complex procedure, the EEG monitor sounded a loud alarm that alerted the operating room staff that the normal pattern of electrical activity displayed in the brain at the beginning of the operation had suddenly changed to a straight line indicating weak or no electrical activity. However, since the heart-lung bypass machine was maintaining the patient's vital signs, what should the surgeon and her staff of medical technicians do? Should her staff continue on the basis that the patient was alive or was the patient dead?

The impact of medical technologies on the increasing occurrence of situations like these cases has required medical professionals and society to reexamine the definition of death. In essence, the advancements in medical technologies that delay or prevent death have actually hastened its redefinition (Penticuff, 1990).

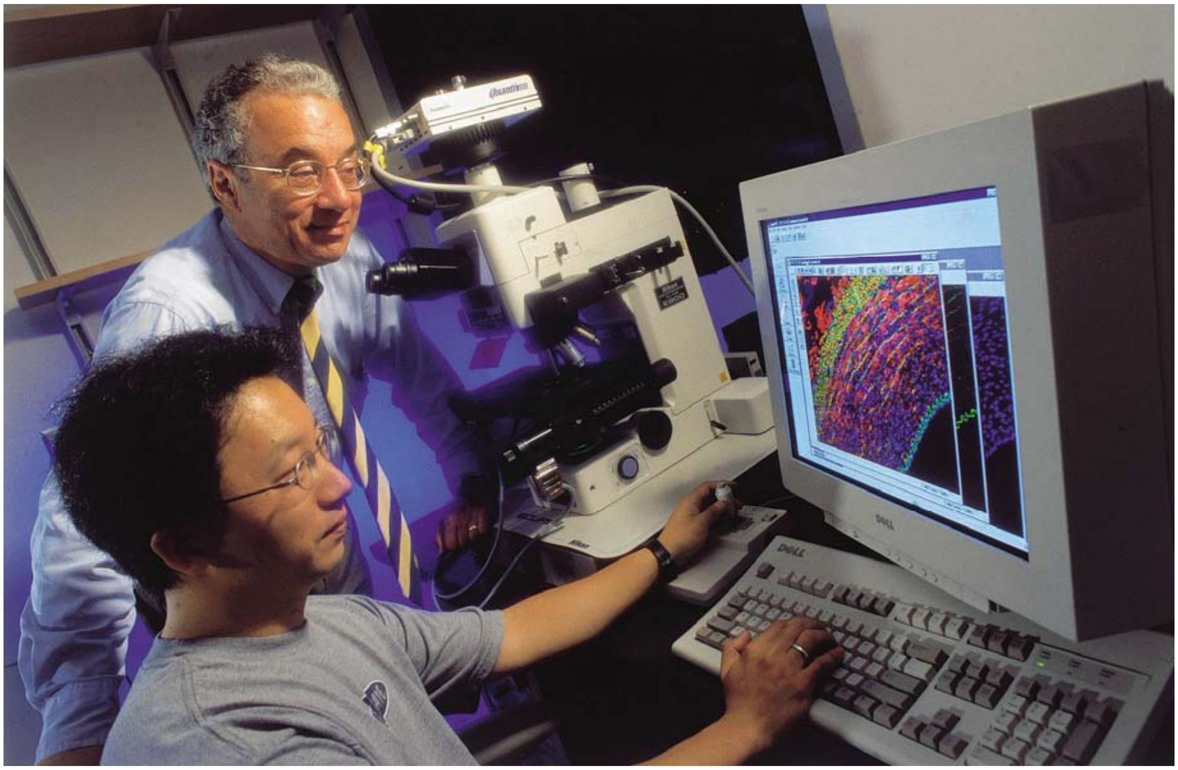


Photo by Gary Meek

Using computers with software color enhancement connected to a high-powered microscope, scientists can view organic compounds with high clarity.

Medical Concerns, Ethics, Decision Making, Social Issues, and Codes of Conduct

The Cases of Karen Ann Quinlan and Terri Schiavo

Medical technology has created new ethical dilemmas for medical professionals. Medical technology has forced the re-evaluation of the traditional definitions of life and death. The concept of birth is now subject to debate as live fetuses can be removed from the womb many weeks prior to traditional delivery. The concept of death is also being revisited as patients can now be resuscitated after prolonged heart, lung, or even brain failure. The ethical considerations of death and when it occurs can be illustrated through two cases: one hallmark case in the 1970s and a recent case still unresolved.

In the mid-1970s, Karen Ann Quinlan was the first modern icon of the debate regarding the right-to-die versus the ability of a medical technology to keep a patient "alive" long after the traditional indicators of cardiac or respiratory failure. The 21-year-old Quinlan collapsed and lapsed into a persistent vegetative state after ingesting alcohol with prescription tranquilizers at a party. Despite severe brain damage and a coma, she was not considered dead because her cardiac and respiratory functions could be maintained using machines. Her family waged a much-publicized New Jersey legal battle and succeeded for the right to remove her from the life support technology that kept her breathing. However, Quinlan kept breathing after the respirator was unplugged and remained in a coma for almost 10 years until her death of acute pneumonia in 1985.

In 1990, 26 year-old Terri Schiavo went into a chronic vegetative state as a result of cardiac arrest due to a potassium imbalance. She was not diagnosed as comatose, but was so brain-damaged that she seemed robbed of any cognitive ability. After eight years, her husband sought to withdraw the feeding tube to allow her to die, but her parents and sister wanted to continue supplying her body with food and water claiming that Terri might eventually be rehabilitated. Initially, the courts ordered the feeding tube removed in 2001, but the parents received a temporary legal injunction to restore the tube. The controversy escalated when Terri's feeding tube was removed by a court order for the second time in 2003. Then, in an unprecedented move, the Florida state legislature passed a law tailored to her case that authorized the state governor to issue a one-time stay to reinsert the tube. The final outcome of the case remains pending at the time of this writing.

As medical professionals, sociologists, legal experts, and judges attempt to untangle the medical, ethical, and constitutional questions, technology becomes a symbol of both vital force and antagonistic purpose. Medical technology raises questions about the obligations of physicians, and of ethical criteria congruent with innovation development. The elusive resolution of human dilemmas that result from the advancements and capabilities of modern medical technologies could not be more apparent. Is an individual in a state of brain death any less in possession of the characteristics from one whose respiration and circulation are mechanically maintained? It is a matter that society must decide. Until society decides, it will not be clear what is beneficial or undesirable in regard to the intersection of human values, morals, and ethics with respect to innovative medical technologies.

Medical Technology Creates Trade-Offs

Historically the definition of death has been closely related to the extent of medical knowledge and the availability of technology. For the centuries prior to artificial respirators, death was defined as the absence of breathing. It was often believed that human existence resided in the *spiritus* (breath); its absence was indicative of death. With the advances in knowledge of human physiology and the development of medical technologies to revive a person who is not breathing, attention then turned to the pulsating heart as the focal point in determination of death. However, this view changed with the addition of technological advances in supportive therapy, resuscitation, cardiovascular assistive devices, and organ transplantation (Dickerson, 2002).

Courtesy Poudre Valley Hospital

A laboratory technician prepares a slide for analysis.

As the knowledge of the human organism increased, it became apparent that one primary support of life was blood and one of the critical components of blood was oxygen. The advent of diagnostic technology to monitor a patient's blood gas levels led to the understanding that all vital organs require oxygen. Hence, any organ deprived of oxygen for periods greater that three minutes begins to suffer damage. The critical functions of the brain are particularly sensitive to oxygen depravation and irreversible damage to brain tissue results. Consequently, the evidence of death began to shift from the pulsating heart to the vital functioning of the brain. Once the technology of the EEG was introduced to monitor the brain's activity, another factor was added to the definition of death. The moral resolution of the death from lack of brain function perspective argues that when the brain is irreversibly damaged, so are the functions that are identified with self and human characteristics, such as memory, feeling,

Courtesy Poudre Valley Hospital

Hospitals use medical telemetry devices to monitor patient vital signs and other important parameters by transmitting this information using wireless technology to a remote location such as a nurses' station.

thinking, and knowledge. As a result, it became widely accepted that the termination of activity of the lungs, heart, and brain defined clinical death. The irreversible cessation of functioning of all three major organs was required before anyone was pronounced dead (Humber, 1991; Ott, 1995). With the development of advanced medical technologies that supported artificial respiration, the medical profession encountered an increasing number of situations where a patient with irreversible brain damage could be maintained almost indefinitely. Once again, new medical technology advancement created the need to reexamine the once simple definition of death. Patients may, however, select criteria for the level of medical intervention through an advance directive.

Social Impacts

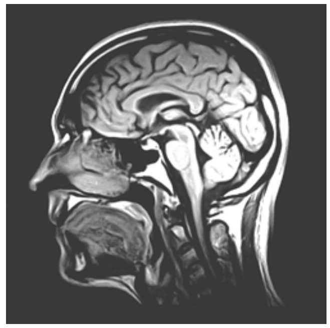
One of the greatest social concerns regarding medical technology is its cost versus benefit. Medical technology increases the cost of medicine making it more difficult for people with low incomes to afford quality care. There is the criticism that reliance on machine technology to produce objective measures and reduce potential liability results in greater cost to the patient. At the same time, there is an increasing consensus among citizens in Europe and the United States that it is the obligation of society to provide health care for citizens. Medicare and Medicaid are two examples of programs that were created by the U.S. Government to subsidize the cost of health care for seniors and low income families.

Another concern is that medical technology enlarges the physician's knowledge of disease, but it also creates a dependence upon machines and laboratory experts. This creates the risk of making medical judgments based solely on technical data without allowing for the possibility of error or considering the patient's views. Doctors who have an overdependence on chemical laboratory tests or x-rays for diagnostic purposes without regard to their relevance may actually be putting the patient at greater risk. The emphasis on what diagnosis the technology provides rather than what the patients says or the physician's professional judgment results in potential division between doctor and patient. The overall consequence is that the physician spends less time with patients, but requires greater amounts of data for an accurate diagnosis at higher cost. Nonetheless, concerns in the medical community regarding the risks of over-reliance on medical technology have not changed the practice of depending on it.

Precision in medical diagnosis hinges on three characteristics: the consistency or stability of the phenomena (disease or illness) being measured, the intrinsic accuracy of the measure or test used (also known as repeatability), and the ability of the observer (physician or technician) to accurately record and interpret the data (known as reproducibility). Medical technology has improved the repeatability of the measures used to diagnose and treat illness. However, new diseases and illness continue to wage war successfully against humankind (e.g., acquired immune deficiency (AIDS), amyotrophic lateral sclerosis (ALS), Parkinson's disease, cancer, flu, and the common cold). Their persistence indicates the powerlessness of the use of medical technology to address unpredictable or unstable ailments. The use of medical technology has improved the accuracy (reproducibility) of medical diagnosis, but it has not eliminated human error as evidenced by the continuing and sometimes tragic medical mistakes. Technology will always be grounded in the people who use it and the medical systems in which it is applied.

Courtesy of Harmony Imaging Center

Ultrasound machines monitor the health of a fetus.



An early sagittal Magnetic Resonance Image (MRI) of the brain.

The Nature of Medical Technology

Understanding Science and Technology
Science is concerned with the study of natural world and the interrelationship between the physical, biological, psychological, and social worlds. Scientists use ideas generated through particular ways of observing, thinking, experimenting, and validating. Thus, science could be described as a world view, a method of inquiry, and as an enterprise of complex activity (AAAS, 1990). The union between science, mathematics, engineering, and technology creates a powerful combination for the development of knowledge and capabilities to extend human potential.

Scientists hold the view that the natural world is understandable and can be explained or predicted using historical data, experimental findings, and methods of quantitative or qualitative analysis. However, scientists recognize that this understanding is subject to change based on new information or theory and that some of the natural world will never be understood completely. Additionally, science:

- demands evidence,
- uses both logic and imagination,
- seeks objectivity,
- has a professional code of ethics,
- avoids prescriptive conclusion,
- and is complex (AAAS, 1990).

Science is a collection of disciplines that are in continuous states of development. Disciplines such as physics, biology, astronomy, and sociology are rapidly changing or being modified into other fields such as astrophysics or sociobiology. Science does not have fixed borders, but it is defined by differing levels of discovery and overlapping interest. A critical tenet of medical technology is that it is highly dependent on the integration of sciences such as acoustics, chemistry, electronics, mechanics, and optics. Without these areas of scientific investigation, medical technology would not be possible.

Technology is the modification of the natural environment in order to satisfy perceived human needs and wants (ITEA, 2000). Generally, there are three layers of the meaning of the word technology. First, as a physical artifact, machine, or an instrument; second, as an activity, or as a means to accomplishing a goal, and third, what people know (Howell, 1996). Rogers (1984) asserted that "technology is a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome" (p. 12). In other words, technology provides human beings with the ability to modify their environment. In the broadest sense, technology extends the abilities of the human beings to create, innovate, or change the world (AAAS, 1990). Technology also has other shared characteristics. In general, technological systems:

- require control to keep them operating correctly,
- always have unintended side effects,
- are prone to failure over time,
- interact strongly with social systems,
- and are complex (AAAS, 1990).

Technology generally consists of two components: tangibles and intangibles. Tangibles are the physical elements associated with a technology such as the equipment, material, or product. Intangibles are the knowledge, skills, procedures, principles, and information base required to successfully implement the technology (Rogers, 1983). The most profound technologies are those that slowly disappear by weaving themselves into the fabric of everyday life until they become indistinguishable from it (Weiser, 1991).

What is the Nature of Medical Technology?

Medical technology is designed to improve the detection, diagnosis, treatment, and monitoring of disease and illness. Medical technology uses applied mechanical, chemical, mathematical, and computerized knowledge systems (AAAS, 1990). The nature of medical technology is contextual, interdisciplinary, interdependent, and systems-based.

- Medical technology is dependent on the application, purpose, environment, and setting in which it is applied.
- Medical technology draws on knowledge, information, and theory from many fields of study.
- Medical technology has interdisciplinary linkages with many other disciplines such as science, arts, humanities, mathematics, and engineering.
- Medical technology, science, mathematics, and engineering have become so interdependent that they can scarcely be separated (AAAS, 1990).
- Medical technology is systems-based (i.e., it represents a collection of devices, procedures, and knowledge).

Courtesy Garth Englund Blood Bank

Patients can now donate blood using a machine that simultaneously extracts blood platelets, plasma, and red blood cells.

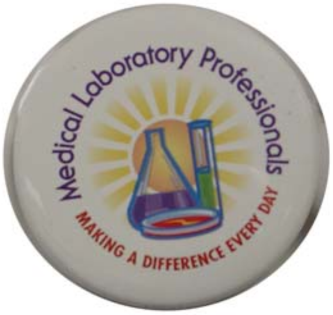
- Medical technology consists of energy forms (mechanical, optical, electrical, acoustical, etc.) applied to body systems (circulatory, digestive, muscular, respiratory, etc.) for specific diagnostic or therapeutic purposes (Evans, 2003).

The Office of Technology Assessment (OTA) (1982) defined medical technologies as drugs, devices, medical and surgical procedures, and organizational and support systems within which medical care is delivered. The Food and Drug Administration (FDA) classified medical technology as diagnostic, therapeutic, monitoring, prosthetic, surgical, laboratory, testing, and miscellaneous devices. The FDA and the European Union (EU) both define medical technology separately from pharmacological, immunological or metabolic methods, but those methods may assist the functions of medical technology. Pharmaceutical drugs or vaccines achieve their principal intended action in or on the human body through organic chemical action (IOM, 1985) and are more appropriately defined as a *biomedical technology*. Medical technologies are generally applied for six purposes: prevention, diagnosis, treatment, rehabilitation, patient support, and administration (OTA, 1978). If one applies these definitions, then medical technology is the application of devices, procedures, and knowledge for diagnosing and treating disease for the purpose of maintaining, promoting, and restoring wellness while improving the quality of life.

Diffusion of Medical Technology
Diffusion refers to the spread of an innovation over time in a social system (Rogers & Shoemaker, 1971). The diffusion of medical technology can be generally described using the

Courtesy Ferro Corporation

Researchers at corporate sponsored research centers are essential for providing primary research and technical support for the development of core medical technologies.



Courtesy Poudre Valley Hospital

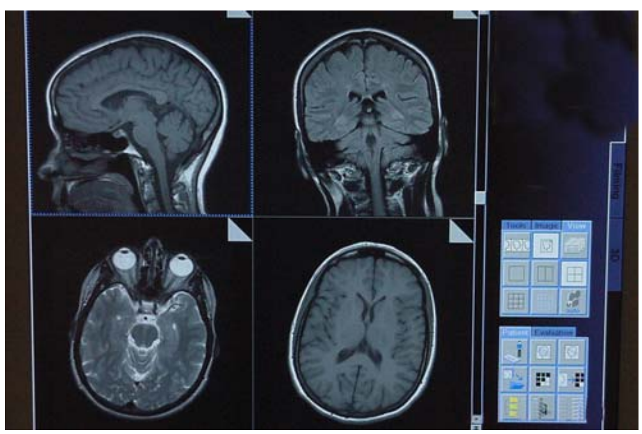
People who work with medical technology are trained professionals.

innovation development process model (Rogers, 1983). The process of developing a medical technology starts with the recognition of a problem or need. This problem is a result of a social construction and is based upon both scientific/technological expertise and political forces. Medical technologies developed to address a problem or need generally come from the interaction between basic and applied research. Basic research is the development of scientific knowledge for the sake of knowledge; it does not have a specific purpose or objective. Conversely, applied research is the specific investigation of a technology to solve practical problems. Applied research uses basic research as a starting point. Occasionally, a medical technology is discovered by accident such as the invention of the stethoscope or radial keratotomy eye surgery.

Once a technology is identified and tested through research, it is then developed by putting it into a form that is likely to meet the expected needs of those who will adopt the technology to solve the identified problem. This form typically includes a prototype or model of the innovation. Once a prototype is successful, it is converted into a product or service for sale in the marketplace. This process includes production, packaging, marketing, and distribution of the innovation and is called commercialization (Rogers, 1983; IOM 1985). Development of medical technology typically involves extensive testing before being accepted as common practice. Because medical technology is inextricably linked with human beings, it creates a need for extra caution and care with respect to implementation. Often, government approval is required for implementation. Once implemented, new medical procedures or tools are introduced through medical journals and direct instruction or training.

The diffusion and adaptation of a medical technology takes place through communication channels such as consensus development, a technique developed by the National Institutes of Health (NIH), to bring together scientists, practitioners, and consumers to determine if new innovations are safe and effective. However, most of the time, the diffusion of medical technology happens by chance and is highly dependent on factors such as prevailing theory, the innovation itself, the clinical or practical setting, the attributes of the potential adopter, regulatory constraints, financial incentives, and the methods used to evaluate the innovation (IOM, 1985).

The final phase of innovation development is the consequence of the technology. Consequences are the changes that occur, both positive and negative, as a result of the adoption or rejection of a technology. Not all medical technologies are adopted and some are discontinued after their introduction. An example of discontinuance was the banning of silicon implants because of leakage problems. An example of non-adoption is the rejection of certain types of birth control because of religious, social, or health concerns.



Courtesy Harmony Imaging Center

Modern imaging technology has made it possible to see parts of the body that were previously visible only after death.

One criticism of the diffusion process is that there is no coherent system or organization that comprehensively monitors, collects, indexes, and disseminates information on medical technology. The effects of this are that some needed medical technologies may never be realized or be implemented too late while other technologies are commercialized without thorough evaluation. Another criticism is that the diffusion process is too slow with few methods for identifying innovation knowledge gaps or setting priorities for the evaluation of critical technology (IOM, 1985).

Technology Transfer

Technology transfer is the communication of information from research and development to the users or vice versa. Technology transfer also occurs when an innovation is transferred to another application as an idea, prototype, or useful product. There are many examples of technology transfer such as applications that began as military or space exploration and later became commercial products. Also, medical technologies develop as a result of breakthroughs in other disciplines. Medical technologies can also transfer to other non-medical commercial applications. The development of Computed Tomography (CT) scans is an example of a medical technology that now has a variety of other uses. The imaging techniques essential in many of the sensing technologies carry over into areas of fine art, drawing, and photography (Evans, 2003). Technology that is not successful in medicine may prove successful elsewhere and vice versa. Figure 1 graphically depicts this process.

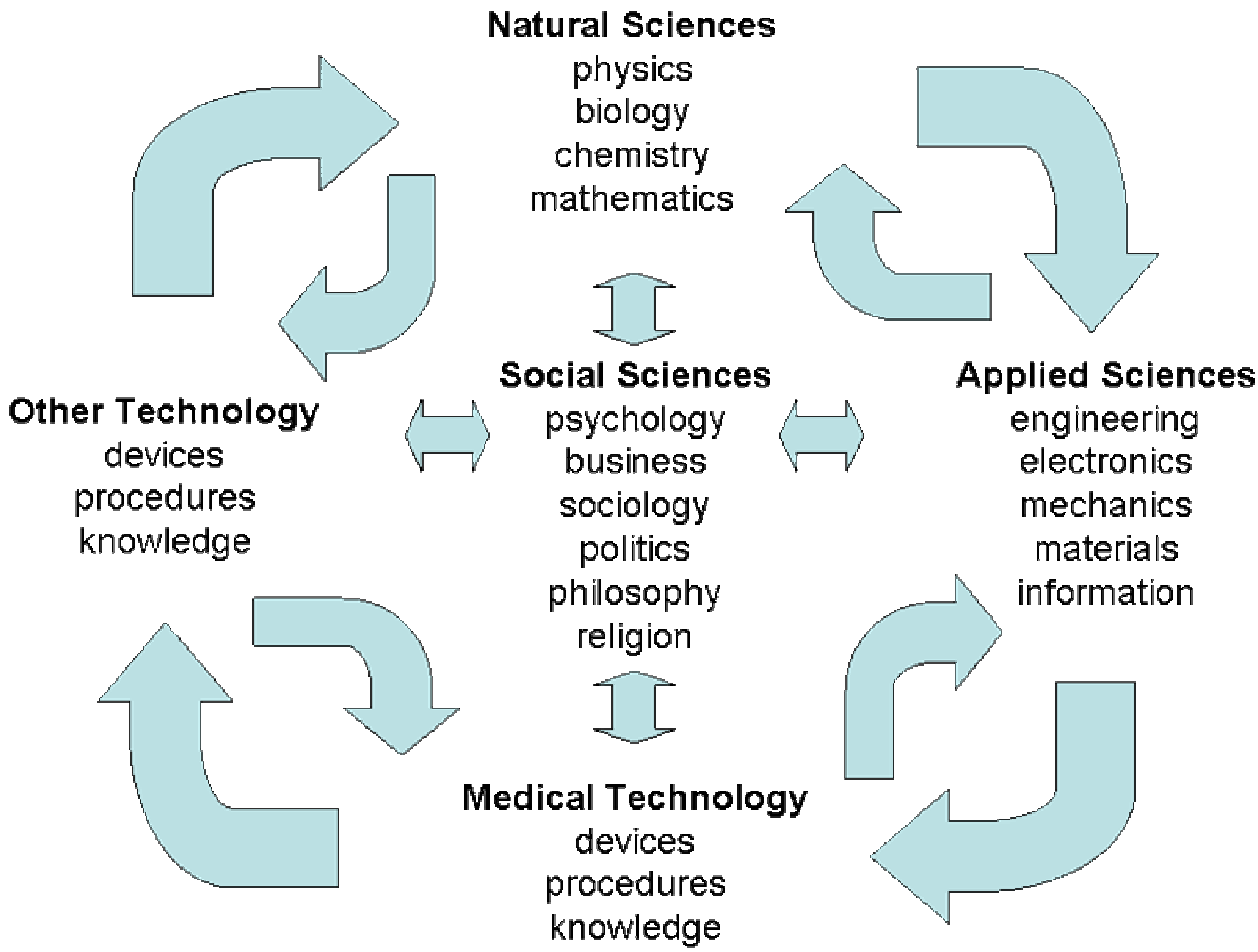


Figure 1. Technology Transfer Process

An Example of Technology Transfer

The Development of Computed Tomography (CT) Scanning Technology

The development and use of a specific technology can be very complex. The CT scanner was developed by combining advances in computers, mathematics, instrumentation, and x-rays. Based on the conventional principles of x-rays, where structures are differentiated by their density and ability to absorb energy, CT scanners combined and improved several technologies resulting in a clearly defined three-dimensional perspective of low density body structures. This technology involves x-raying successive cross sections of the body to build, with the aid of a computer, a three-dimensional image. Tomography overcame the two dimensional limitations of x-ray by showing objects in a particular plane. Simultaneously, instrumentation made the measurement of the x-ray radiation easier. Advanced mathematics made the reconstruction of images from large sets of tomographic data possible, and modern computers provided the capability for the mathematical models.


Courtesy Harmony Imaging Center

Modern CT Scanner

Working independently, Alan Cormack, an American physicist, and British engineer Godfrey Hounsfield developed the first workable CT instruments in 1967. The first prototype scanned only the head and was used in 1971. The first commercial model was used at the Mayo Clinic in the summer of 1973 and began to be installed on a wide-spread basis in 1974. Currently, 6,000 scanners are in use in the United States. Because of advances in computer technology, scanners are now much faster and can make images of the entire body. Technology improvements have also led to higher-resolution images, which improved diagnostic capabilities. For example, a CT scan can now show doctors small nodules or tumors, which they could not see using x-ray. The CT scan is also known as a CAT (computerized axial tomography) scan.

The diffusion of the CT scanner within the medical community was more rapid than that of any other modern medical technology that has been statistically documented. This dissemination occurred in spite of its high price. (Early head scanners cost $300,000 and whole body scanners are over $1 million dollars today.) Most CT scanners were first adopted in medicine because of the strong financial incentives associated with their use in hospitals and the fear of malpractice suits by doctors. This was not the case for the CT scanning technology that was later applied outside the field of medicine.

Medical Computed Tomography technology is now providing important solutions outside of medicine in industry and business. Some of the current applications for CT scanning are:

- screening of luggage for explosives at airports
- scanning logs in the timber industry for grain patterns or defects
- border patrol screening and drug interdiction
- raw diamond scans prior to cutting
- scanning of food for foreign particles or dense material
- non-destructive testing of durable goods

Thus, it appears that CT scanning is a technology that has come full circle in its development and application. The CT scanner represents a technology that was developed from basic scientific principles for a specific medical application and is now being used for purposes other than medicine.

Section II. Structure of Medical Technology

What will this section cover?
A conceptual framework for medical technology

What will this section help me understand and be able to do?
Identify the key elements of medical technology
Develop a theory of medical technology

Medical Technology Conceptual Framework

Medical technology is the application of devices, procedures, and knowledge for diagnosing and treating disease for the purpose of maintaining, promoting, and restoring wellness while improving the quality of life. A representation of this taxonomy is shown in Figure 2. This section will describe the conceptual structure of medical technology in detail.

Courtesy Poudre Valley Hospital

Medical technicians must possess observational and analytical skills.

Knowledge
All technology starts with knowledge and this knowledge comes from multiple sources. In the case of medical technology, most of this knowledge comes from three primary sources: educational institutions, governments, and the collective or individual knowledge of those in the medical field.

Educational Institutions
Educational knowledge of medical technology resides in hospitals, clinics, universities, public libraries, medical laboratories, and the Internet. The educational knowledge of medical technology is both general and specialized. This knowledge consists of information or raw data, the contextual or applied setting, and the foundation or source on which the knowledge was based. General educational knowledge about medical technology is common knowledge and is taught at public schools or shared at medical institutions. This primer represents the development of general education in medical technology for the purpose of increasing general knowledge about the subject. Specialized knowledge of medical technology is discipline-based and usually resides in educational departments at institutions of higher learning or medical schools. Specialized medical technology knowledge might include the specializations and unique disciplines of cardiology, neurology, homeopathic remedies, pediatrics, chiropractic, anesthesia, or veterinary medicine.

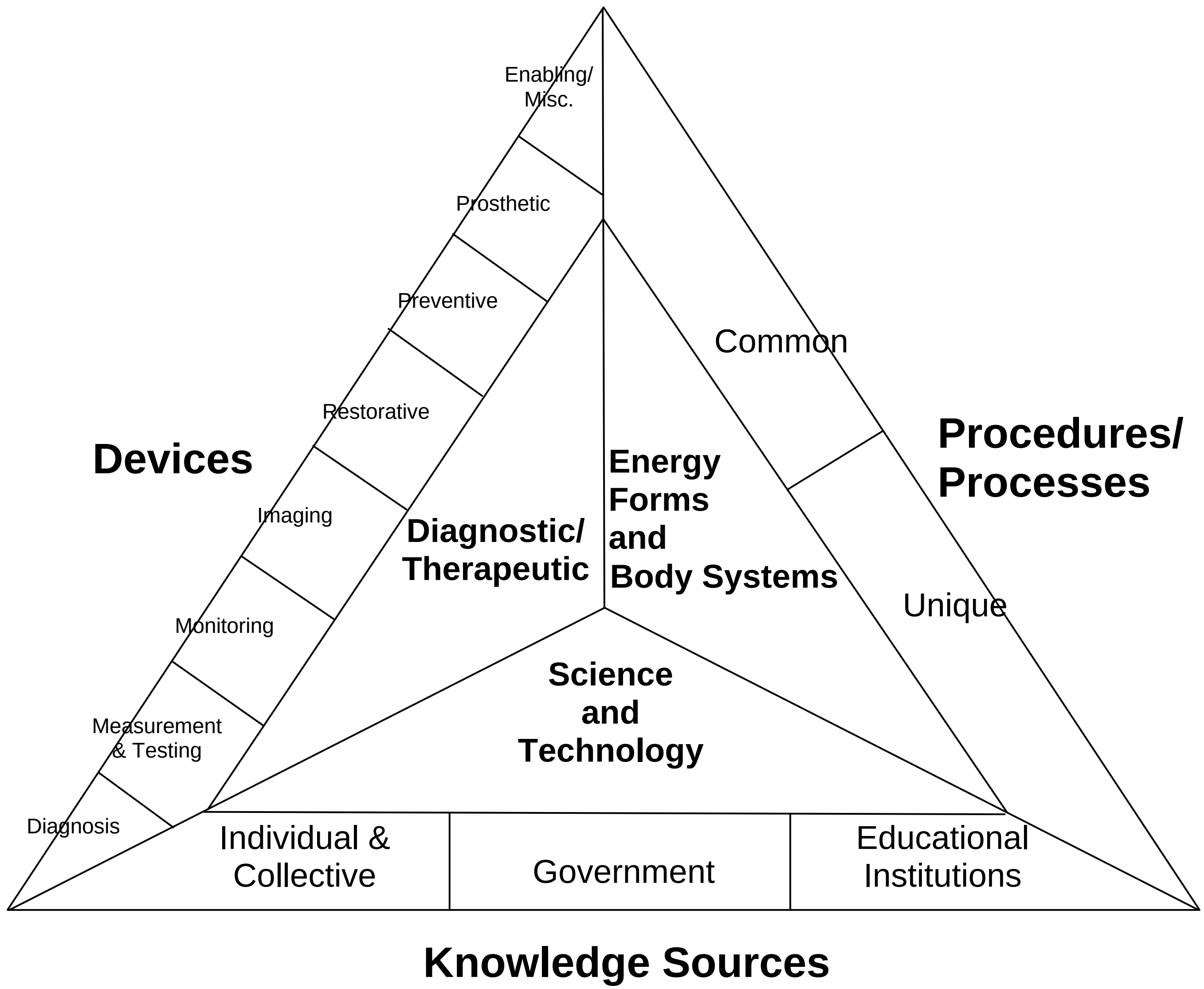


Figure 2. Medical Technology Conceptual Framework

Governments

A second source of medical technology knowledge comes from governments. There seems to be an increasing concern among democratic societies for access to quality health care. In fact, the right to use medical technology and services is beginning to be viewed as an obligation of governments to its citizens. It is not surprising, in this environment, that governments take a serious interest in the application and administration of medical technology knowledge. Because of the importance and cost of medical services, governments typically have many research and regulatory agencies that set standards, approve new medical devices or techniques, and control costs. Much of the medical research in the United States is funded by the federal government through universities or medical centers. Some of the common research and regulatory agencies include the National Institutes of Health (NIH), the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the Office of Health Technology Assessment (OHTA). These governmental agencies set agendas for research funding, investigate outbreaks of infectious diseases, monitor or approve new drugs and devices, and evaluate medical technology.

Individual and Collective Knowledge

The third source of medical technology knowledge is the individual and collective knowledge that resides within the minds of people and the organizations that practice medicine and health care. This is the knowledge possessed by people such as researchers, physicians, radiologists, technicians, and laboratory workers in hospitals, clinics, insurance agencies, private companies, governments, and schools. This source of knowledge is the most complex of the three because it exists in various locations and formats. It can best be explained using the conceptual model shown in Figure 3.

Common knowledge about medical technology is both known and available. One can go to the local library or Internet and gather this knowledge. Common knowledge is characterized by its accessibility, availability, and general understanding among the local population or society. An example is the general knowledge of the existence of x-ray technology or the awareness of medical procedures such as appendectomy or tonsillectomy. Knowledge that is known and available can be easily retrieved and stored with little effort and is the basis for standard operating procedures or the use of common appliances.

Tacit knowledge, like common knowledge, is known, but it differs because it is hidden from

Known and Available (Common Knowledge)	Known and Hidden (Tacit Knowledge)
Unknown and Unavailable (Ultimate Truth)	Unknown and Hidden (Undiscovered)

Figure 3. The Conceptual Model of Knowledge

the general population. This knowledge is known, but it resides narrowly within certain people, companies, laboratories or disciplines who have use for it. Tacit knowledge is characterized by limited or proprietary access. Selected individuals or organizations possess this knowledge, but do not necessarily share it with the wider population. As such, this knowledge is gained only through asking specific questions of people who know, purchasing it, or by being exposed to a discipline or environment where the knowledge is used. An example of tacit medical technology knowledge is the technique used by a surgeon to suture a head wound or the type and model of the machine used to perform CT scans on animals. Knowledge that is known and hidden requires more effort to acquire and is usually specialized in nature.

Courtesy Poudre Valley Hospital

Cardio-catheterization x-ray equipment allows physicians to see inside the coronary arteries of the heart.

The last two types of knowledge, undiscovered and ultimate truth, are not as useful for a discussion about medical technology, but they are of theoretical interest. Undiscovered knowledge is knowledge that exists, but it has not yet been uncovered. For example, in the field of medical technology, scientists know how molecules are arranged and how they interact to create materials and compounds. Yet, the scientists have not yet discovered the technology to be able to manipulate these molecules into medical devices that can target and cure diseases like cancer or leukemia. Theory indicates the knowledge is possible, but the actual understanding of how it might work remains unknown and hidden.

Ultimate truth is the most controversial as it assumes that some knowledge will always be unknown and also unavailable, even to those who actively seek it. The positivist purist would claim that all knowledge is subject to discovery sooner or later. Most scientists agree that even if there is no method of securing complete or absolute truth, increasingly accurate approximations can describe the world and the way it works (AAAS, 1990). However, for the purposes of this model, one could also argue that there will be some scientific or technical knowledge that will always remain unknown and unavailable.

Why is Knowing about Medical Technology Important?

Knowledge of medical technology is important for several reasons. First, the field of medical technology is expanding. There continues to be an increasing demand for technical skills and people who have a basic level of medical technology understanding. The demographics of the population in the United States indicate that the opportunities for jobs in health care will expand (BLS, 2004). Many of these opportunities will require a fundamental knowledge of medical technology. Second, more and more people interact and deal with medical technology on a personal level then ever before. Knowledge about the field of medicine and where to get valid information are becoming more important. People who may be caring for older family members in the future should be familiar with information on the aging process or the medical services and devices available for seniors. Individuals may also encounter situations in their own lives where knowledge of medical technology is helpful as they seek diagnosis for illness or become interested in alternative treatments. In addition, successful diagnosis, treatment, and doctor-patient relationships are built upon the ability of both parties to communicate clearly with language that describes what is happening and what is likely to occur in the future. Thus, medical technology knowledge is of great importance to the health and economic well-being of society.

budgetstockphoto.com

Procedures

Procedural technologies can also be thought of as processes. In manufacturing, there are certain processes that are used throughout industry for different products and different applications. Processes such as forming, casting, molding, conditioning, joining, separating, finishing, and assembly are universally acknowledged within the field of manufacturing as standards for production operations. However, some operations are unique to the product or application. Medical technology, like other disciplines, uses common and unique processes.

In the practice of medicine, there is a cyclic relationship between diagnostics and therapeutics. The process begins with a diagnostic measurement followed by therapies or treatment. The process then returns to diagnostics to assess the effectiveness of the treatment. One of the unique characteristics of medical technology processes is that they are generally applied to human body systems such as circulatory, respiratory, endocrine, or digestive. The processes are made possible through the use of various energy forms; forms normally associated with the study of physics, such as mechanical, electrical, magnetic, or thermal. Therefore, medical technology procedures are both common and unique, use energy forms applied to human body systems, and are generally diagnostic or therapeutic.

Common Procedures

The common procedures used in medical technology are those used frequently and across the medical spectrum of diagnosis and treatment. They are procedures commonly applied by physicians and medical personnel with the general population and are well-known by both practitioners and patients. Some of the common procedures used in medical technology are the following:

- *Surgical* procedures such as separating or joining parts of the body, excision of tumors or disease through invasive methods or lasers, repair or replacement of bones and common joints, wisdom teeth extraction, and arthroscopic or laparoscopic surgery.

- *Rehabilitative/Preventive* procedures such as sanitation of instruments and

Courtesy Poudre Valley Hospital

Bio-hazard waste containers decrease the transmission of disease.

operating rooms; resuscitation, traction, personal protective equipment and clothing worn by physicians, nurses and technicians; bio-hazardous waste disposal; teeth cleaning and cavity repair; physical exercise therapies, and psychiatric or psychological therapies.

Courtesy Poudre Valley Hospital

Automated equipment counts the number of white blood cells from samples.

- *Laboratory* procedures such as specimen analysis methods, diagnostic microscope, centrifuge, urinalysis, or blood work practices.

- *Information and Communication* procedures such as the application of medical software and artificial intelligence systems; use of telemedicine for diagnostic and therapeutic treatment, statistical analysis of medical data; and use of monitors, pagers, cell phones, or video.

Unique Procedures
The unique procedures used are generally associated with medical specializations such as alternative medicine, radiology, anesthesiology, neurology, and ophthalmology. While they may use procedures and processes that are common within the specialization, their approaches tend to utilize internal tacit knowledge. Information that is shared inside the specialization may be common to the specialists, but the procedural knowledge itself is not widespread among the medical technology community. A few examples of the many unique medical technology procedures are outlined below.

- *Alternative therapies* are medical procedures outside what is traditionally taught in urbanized Western medical schools or covered by medical insurance. They include, but are not limited to folk medicine, herbal medicine, diet programs, homeopathy, faith healing, new-age healing, chiropractic, acupuncture, naturopathy, massage, and music therapy.

- *Radiology* is medical imaging techniques using advanced computers and other complex equipment to allow doctors to see inside a patient's body such as x-ray or CT scans. Although the word radiology implies radiation, not all of the techniques actually use radiation. Although radiology is most commonly used for diagnosis, it is also used for treatment. Most of the actual imaging is carried out by highly trained technologists. The images are then analyzed by specially trained doctors called radiologists.

- *Anesthesiology* is the medical specialty concerned with the administration of

Courtesy Colorado State University Human Performance Clinical/Research Laboratory

The Graded Exercise Test (GWT) measures heart rate.

medication to aid in pain management and sedation. An anesthesiologist also monitors vital signs, heart rates, and other life functions while a patient is undergoing surgery.

- *Neurology* is the scientific study of the nervous system (i.e., brain, spinal cord, peripheral nerves, and muscles) and its diseases. Specialists in this area treat disorders such as seizures, developmental delay, neuromuscular diseases, and severe or complicated language/learning disabilities.

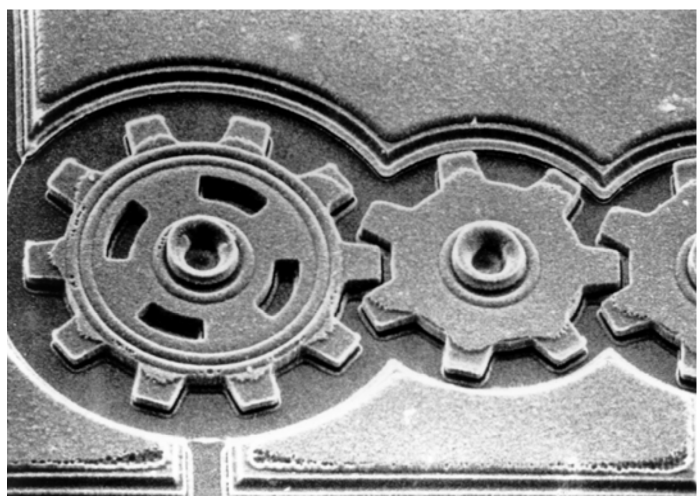
- *Ophthalmology* is the diagnosis, treatment, and management of eye diseases, including prescribing corrective lenses, corrective/refractive surgery, and surgery to remove cataracts and diseased eye tissue.

Why are Medical Technology Procedures Important?

The procedures used in medical technology are important because procedures both come from and contribute to the body of medical knowledge. Procedures act as the link between what is known and what is done. They form the relationships and connections in medical technology. Procedures are also the basis for assessing the impact of medical technology on society. Some medical procedures such as abortion and human cloning are controversial. Procedures reflect the area of medical technology where decisions of appropriateness, cost, resources, and feasibility begin to be important indicators of acceptance or use. Medical processes and procedures sometimes procedures create unintended impacts in spite of rigorous evaluation by the FDA and medical community. Procedures are the "operating software" of medical technology.

Devices

Medical devices involve all types of physical technology and forms of energy (e.g., mechanical, acoustical, electrical, chemical, optical, thermal, etc.). The devices can be simple (thermometer, eyeglasses) or complex (CT scans, x-rays). In general, medical devices fall into two categories: (1) devices that diagnose or sense the body and (2) devices that treat the body or are used for therapeutic purposes. Diagnostic devices can be classified as: measurement and testing (or biometrics), monitoring, and imaging. Treatment devices can be classified as restorative, preventative, and prosthetic. Other devices are not easily classified such as enabling devices that are used for miscellaneous purposes. Some devices, such as nanotechnology (the science of creating highly miniaturized machines that work at the molecular level), could be classified under multiple categories because they can potentially be used for a variety of purposes.



Courtesy AT&T Bell Labs

Gears smaller than a human hair created using nanotechnology.

Diagnostic Devices

- *Diagnostic* devices assist the physician or technician in the diagnosis of illness or disease using indirect methods. Diagnostic equipment might include the microscope, stethoscope, blood pressure

Courtesy Poudre Valley Hospital

Machine used to inject x-ray dye into patients for angiography.

device, or instruments for analyzing blood or urine.

- *Measurement and Testing* devices are also known as biometric devices because they directly measure or sense the operation of human body characteristics, functions and components. These devices might include electrocardiogram (ECG or EKG), fingerprints, eye retina scanners, and voice, hand, or facial pattern recognition systems. A growing field of biometrics incorporates the measure of human physical attributes for the purpose of identification and authentication.

- *Monitoring* devices are used to monitor and detect anomalies in human components or functions and alert the user of potential or immediate changes to body chemistry, activity, or operation. They might include the devices used to monitor the vital signs of patients during surgery or in an intensive care unit (ICU).

- *Imaging* devices allow the physician to view human functions, operations, or components inside the body through non-invasive means. They might include devices such as x-ray, magnetic resonance imaging (MRI), computerized tomography (CT), ultrasound, or Positron Emission Tomography (PET) using radioactive dyes.

Therapeutic Devices

- *Restorative* devices restore critical human functions and operations through modification or adjustment without replacement of the function. These devices might include the dialysis machine, heart-lung machine, defibrillator, respirator, pacemaker, cardiovascular assistive devices, robotics, insulin pumps, hearing aids, glasses, braces, or wheelchairs.

- *Preventive* devices are closely related to measurement and testing devices, but they are more for the prevention of adverse consequences or the verification of body changes. They might include

Courtesy Poudre Valley Hospital

Much of the modern medical technology today is automated.

devices such as diabetes test kits, heart rate checkers, medicine pumps and patches, and fetal monitors

- *Prosthetic* devices restore human function or capability through replacement of the damaged or missing component. Prosthetics include artificial heart valves, artificial blood vessels, functional electromechanical limbs, reconstructed skeletal joints, artificial kidneys, and implants.

Enabling/Miscellaneous devices are simple tools that extend or assist the physical capabilities of the medical professional. They might include hand tools such as forceps, dental picks, clamps, or surgical knives. These devices could be used for diagnosis, treatment, or both.

Why are Medical Technology Devices Important?

Medical technology devices are important because they are the mechanisms through which diagnosis and treatment are delivered. They are integral to medical technology for delivering medical technology procedures and are sometimes considered its centerpiece. Medical devices are certainly one of the first things individuals will think of when asked to describe medical technology. Often medical technology devices are thought of as an extension of the human senses, allowing physicians and technicians to see, hear, touch, smell, and taste beyond their normal range. Imaging technology allows doctors to see inside the human body without opening it.

Courtesy Colorado State University Human Performance Clinical/Research Laboratory

Patients use devices to measure leg pull-strength after surgery for rehabilitation therapy.

Acoustic technology allows physicians to hear inside the body more accurately then using their ears. Optics and microelectronics allow medical professionals to manipulate and move body components while never physically touching them. Laboratory instruments analyze the composition and characteristics of body fluids or tissues more precisely than a specialist could possibly taste or smell.

Summary of the Conceptual Framework

Knowledge, procedures, and devices interact depending upon the context of their application. Medical technology applies all three to satisfy various needs and solve problems. Knowledge of medical technology is inert until it is applied. The processes and devices create the environments that change the world, but they would not be possible without medical knowledge. The applications of medical technology can be knowledge-intensive, procedure-intensive, or device-intensive. Applications can also be combinations of two or three of the above that incorporate knowledge/procedures, procedures/devices, devices/knowledge, or all three. Thus, the framework of medical technology could be described as theoretical, applied, physical, and contextual.

Section III: Teaching About Medical Technology

What will this section cover?
Core areas for medical technology literacy
Medical technology concepts
Educational discussion, curriculum development, and classroom planning

What will this section help me understand and be able to do?
Identify the key concepts and design of a medical technology curriculum
Learn grade appropriate educational vignettes for discussion and reflection

Medical Technology Literacy

Concepts of Science and Technology
The foundation of medical technology rests in science. Scientific principles, levels of inquiry, and scientific methods form the basis for the technological world. The development of ultrasound technology would have never been possible without the scientific knowledge of acoustics. Magnetic resonance imaging would not have been possible without scientific inquiry into magnetic and electrical energy. The medical technologist, armed with knowledge created from science, seeks to create solutions to problems of human suffering, disease, and mortality. As a result, linkages form between science, technology, and body systems that create the area of inquiry called medical technology.


Courtesy Poudre Valley Hospital
A laboratory technician places blood samples in an automated chemical analyzer.

Because of the importance of the relationship between medical technology and the physical body, medical technology interfaces with or is applied to diagnose or treat specific body systems such as the respiratory, circulatory, or endocrine systems. This link is important because it delineates medical technology from other types of technology.

Even though medical technology is strongly linked to human application, it is more grounded in its scientific roots. Thus, it has application in other areas. Many medical technologies are already being used in the area of veterinary medicine. Consequently, the challenge for achieving a level of medical technology literacy is to promote the understanding that science and technology are inseparable and must be learned simultaneously. While the application of medical technology is specific to body systems, it remains grounded in both science and technology.

Core Concepts of Medical Technology

The following are the desired enduring understandings of medical technology:

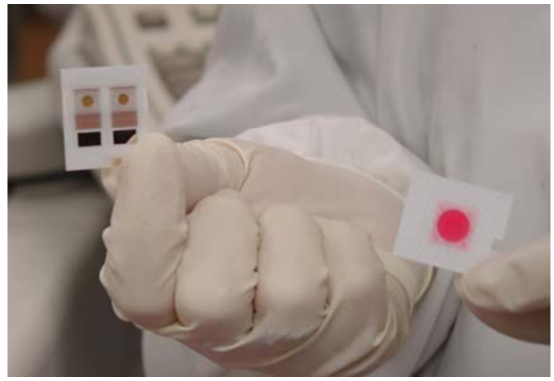
- The study of medical technology requires the development of both science and technological literacy.
- Medical technology applies natural energy forms to various body systems for the purpose of diagnostic or therapeutic outcomes.
- Medical technology integrates knowledge sources, procedures or processes, and various types of devices.
- Medical technology interacts with society and the environment.
- Medical technology has both positive and negative consequences.
- The design of medical technology is generally a structured process while its diffusion tends to be random.
- Students must be fluent with medical technology to be able to work and live with it productively and successfully.

Courtesy Poudre Valley Hospital

A defibrillator administers an electric shock to the heart in order to re-establish normal heart rhythm.

Science and Technology Literacy

One core area is to understand the nature of science and technology. This includes developing an understanding of the characteristics and scope of science and



Courtesy Poudre Valley Hospital

Color chip standards are used to compare human blood samples against known chemical compositions.

technology. Science is typically inquiry-based whereas technology is typically application-based. Science builds knowledge slowly through repetitive inquiry and sophisticated methods. Technology applies scientific knowledge through experiments, practice, or trial-and-error using creative, social, and political methods. The scope of science is infinite; the scope of technology is usually well-defined and has a specific focus. For example, scientists were recently able to grow an artificial eyeball and implant it into a tadpole. Technologists are now working on applying that scientific knowledge to humans.

There is a strong relationship between science, technology, and other fields. The nature of medical technology is contextual, interdisciplinary, interdependent, and systems-based. It draws upon knowledge, practices, and applications from every field of study and has linkages with science, mathematics, and engineering. Alternatively, many medical practices and devices are now being adapted for use in other fields. For example, medical imaging techniques are being used in wood processing industries and medical biometric identification systems are being used for security and access.

Application of Energy Forms to Body Systems

Medical technology typically applies energy forms using devices to various human body systems. These energy forms are well known in physics and engineering and consist of the classifications used to describe the physical world. These classifications are commonly described as acoustic, chemical, electrical, magnetic, mechanical, nuclear, optical, and thermal (McGhee et al., 1999). With regard to medical technology, these energy forms are generally used in combination for an application. For example, ultrasound uses acoustic energy; magnetic resonance imaging uses magnetic energy; positron emission tomography (PET) combines nuclear scanning energy with chemical analysis; endoscopes employ optical and electrical energy; and thermometers make use of thermal energy (Evans, 2003).

Because medical technology is so closely associated with the human condition, it has an inextricable link with the human body. Medical technology applies the various energy forms to body systems for both diagnostic and therapeutic purposes. Some common body systems are the circulatory, digestive, endocrine, muscular, nervous, reproductive, respiratory, skeletal, and urinary systems. Just as an automobile mechanic needs to know something about the application of the vehicle in context (e.g., roads and highways), the medical technologist must also have some knowledge about the body systems where the medical technology is applied.

Knowledge, Processes, and Devices
Medical technology is grounded in scientific and technological knowledge from three sources: educational institutions, governments, and the individual and/or collective. Medical technology employs processes or procedures that are common or unique. These processes interface with body systems in some fashion. Medical technology consists of various types of devices, which also interface with body systems either directly or indirectly. The knowledge,

Courtesy Poudre Valley Hospital

Images that used to be viewed with photographic plates or on paper copies are now available instantaneously via computer software.

procedures, and devices are contextual based on their application.

Interaction with Society and Environment
Another core concept is to understand the relationship between technology and society. Technology does not exist in a vacuum. It is developed by humans, used by humans, and interacts with the environment. Technology affects and is effected by cultural, economic, political, environmental, social, and historical factors. For example, many grocery stores and pharmacies now provide free access to blood pressure monitoring gages (sphygmomanometers) that can be used by the public for general health information in a social environment. No medical diagnosis is provided by these machines, only information. Yet, many people use them for periodic health check-ups or amusement.

Scientists and engineers develop technology first as a response to satisfy perceived human needs and wants. Once basic needs and wants have been satisfied, higher levels of innovation become important, not just because of increased expectations, but also because of the innate need of human beings to create and produce. Medical technology has created new ethical and social issues. New definitions of life and death are now being debated. The cost and access to medical care are now becoming important economic and social decisions.

Courtesy Poudre Valley Hospital

Medical professionals are responsible for the health and well-being of patients in the Surgical Neuro Intensive Care Unit (SNICU).

Consequences

Change and technology tend to produce strong emotional reactions in most people. One strong emotion is a sense of wonder and exploration. When x-rays were first introduced, many fashionable socialites had x-ray pictures taken of their hands or feet as a sign of social status. A second strong reaction to technology is fear. While many were enthralled with the first x-rays, there were some physicians who maintained that clinical examination was still more reliable (Blume, 1992). There were also patients who reacted negatively to x-ray images, saying they revealed death, could invade personal privacy, or see through clothing (Howell, 1995).

Every technological innovation has both positive and negative consequences. While x-rays were found to be extremely useful for finding bone fractures and foreign objects in the body, they were also found to be unhealthy for humans at high or frequent levels of exposure. With the rise of hospitals, machines, and specializations, many people perceive modern physicians as “miracle workers” who can cure or treat almost any illness. However, some would assert that medical care is now less accessible to rural residents, more impersonal, and does not promote the adoption of healthy lifestyles that may prevent disease.

Technologists recognize that new innovations create strong reactions and take steps to alleviate fears and temper the associated sense of awe. Much of this is done through the dissemination of information about the technology. Technologists also attempt to discover or mitigate the unintended consequences that may result from the introduction of the innovation. Mitigation may include changing or redesigning the innovation to better fit the culture or assessing the trade-offs between product performance and individual preferences. In some cases, the technology may not be appropriate for the application and will need to be reengineered for social consumption.

Design and Diffusion
A core concept is the design and diffusion of medical technology. The design of technology is generally limited by physical or economic constraints and the capacity of human imagination. It is also limited by purpose. Technological design must be efficient and effective because of its applied, purposeful nature. In design, there are multiple solutions or trade-offs that must be considered. For example, technicians using Computer-Aided Design (CAD) develop customized solid models of hip-ball joint sockets from information provided from precise CT scans. These solid models can then be used to create patterns using rapid prototyping technology which in turn can be manufactured to produce a perfectly fitting titanium hip replacement joint.

The development and design of medical technology uses a structured approach and is diffused or disseminated through both formal and informal communication channels. The structured design of medical technology starts with basic scientific research that is later applied

Courtesy Poudre Valley Hospital

The intravascular ultrasound machine uses acoustics and high resolution computer rendering to make pictures that accurately represent the characteristics of blood vessels and arteries.

through invention or procedure, which are then developed into prototypes or models, and finally commercialized into products or services for sale. The diffusion of a technology has no coherent system or organization and is highly dependent on non-technical factors. The development of a medical technology has both positive and negative consequences that result in either its adoption or rejection.

Courtesy Poudre Valley Hospital

An echocardiogram uses sound waves to produce an image of the heart.

Fluency with Medical Technology
It is not enough to understand and have knowledge of technology. Today, most people must also have a basic level of fluency with technology in order to successfully interact with each other or use basic services. People also need to be technologically literate in order to assess the technical products, services, the systems available, and be able to make sound choices or decisions about them. The nature of the technological world will require that people be able to manage the technology around them and be able to observe, investigate, test, and analyze its effectiveness. It is highly probable that most people will interact with or need the use of a medical technology sometime during their

lifespan. Knowledge of how to use a heart defibrillator or how to perform cardiopulmonary resuscitation (CPR) may be of great value. In terms of economic impact, according to the Bureau of Labor Statistics (BLS, 2004), the demand for medical professionals with technical skills is among the fastest growing occupational fields. The future of medical technology is likely to have a great impact on the health, wellness, and economic development of society.

The primary reason for the development of medical technology literacy is that the management of technology should not be left in the hands of the uninformed. People who do not understand the potential implications, benefits, or consequences of a technology run the risk of

Courtesy Sam Castro, Univ. of Wis.-Milwaukee *Research Profile Magazine*

Second graders invent their own math games.

misusing it. When people use technology in inappropriate ways, bad things happen. Examples of inappropriate uses of technology are the recent proliferation of nuclear weapons in developing countries or the invasion of privacy using sophisticated software. Medical technology, like other forms of innovation, has the capacity to heal and improve quality of life. However, medical technology used inappropriately can be disastrous and take many lives.

Learning about Medical Technology

The first priority of medical technology education is to provide literacy in medical technology to all students. This literacy will benefit students and society in multiple ways. First, medical technology literacy will create a more diverse pool of graduates who are able and interested in pursuing professional careers in medicine using medical technology. Second, medical technology literacy will create a more informed consumer; a consumer who is able to distinguish and make sound choices regarding treatments and medical services for themselves or others. Third, medical technology literacy will improve the relationships between the professional medical community and patients because they will begin to communicate using common terms and understand both the human and technical limitations of the technology. This will ensure that the technology will be used appropriately rather than just using the latest piece of equipment.

The following section is designed for educators to use as a resource in the development of a medical technology curriculum or the generation of ideas for experiences and activities in the topic. It is organized by grade levels: elementary, middle school, and high school. Each grade level section includes the medical technology concepts appropriate for that group and a vignette example of how a concept might be organized for the classroom.

Elementary (3rd-5th Grade)

The curriculum for medical technology at the elementary level should be organized to help students achieve the basic elements of verbal skills, mathematical skills, and social skills. Their experiences in medical technology should be geared toward knowledge of the basic device technologies, psychomotor skills, and technical-social interrelationships. This study should incorporate related concepts from other disciplines such as science, technology, mathematics, and humanities. Discussion of medical products, devices, and healthcare systems that benefit society is appropriate. Children can be engaged in the design and fabrication of simple medical devices or develop medical procedures for common illnesses and colds. Teachers can also demonstrate the application of common medical devices to build relationships with other subjects. Medical technology education can be part of integrated thematic units that explore the relationship of medical technology to humans, society or the environment. It can also be taught as part of a health and wellness curriculum with a designated time slot.

The materials and resources required for elementary medical technology education are minimal and can include student or teacher prepared items along with basic supplies. In addition, simple medical devices such as a thermometer, stethoscope or sphygmomanometer (blood pressure gauge) can be used to reinforce basic skill development using active learning. Engaging the learners with common household objects designed to inform, prevent, or heal injuries and prevent disease are helpful in establishing a context for medical technology.

Medical technology can be taught in a regular classroom by any qualified elementary teacher. Specific pre-service teacher training is not required at this level, but it could be incorporated into technology education professional development curriculums at teacher preparation institutions. In-service training is helpful in developing teacher confidence through practice and skill development.

3rd-5th Grade Key Concepts

- Context: Integration of medical technology to other disciplines
- Relationships: The use of medical products or systems to inform, heal or prevent disease
- Technologies: Devices that repair or restore body functions
- Applications: Application of common health devices and practices
- Social Impact: Benefits of medical technology
- Processes: Construction of physical models
- Learning Approach: Active learning with common medical devices (stethoscope, microscope, sphygmomanometer, thermometer)
- Supplementary: The role of medical technology in healing

Courtesy Poudre Valley Hospital

A nurse performs an electrocardiogram on an infant.

3rd-5th Vignette

This example describes a method for developing an activity that illustrates how devices can repair or restore body functions. This example highlights a conceptual element of medical technology for grades 3-5 and is congruent with the International Technology Education Association (ITEA) *Standards for Technological Literacy,* Standard 14E, and the American Association for the Advancement of Science (AAAS) *Benchmarks for Science Literacy,* Benchmark 8F.

Mr. D's fourth grade class was studying about health, wellness, and some of the tools used to promote healthy living. During this unit of study, the class talked about the technological advances in health care. One of the girls in the class is physically challenged and uses the aid of a wheelchair. She mentioned that the advances in technology made her new chair lighter, and easier to move around the room. Taking advantage of this opportunity, Mr. D asked the students to think of other devices that repair, replace, or provide mobility for people with disabilities.

The students made a list of all the devices they could think of. The list included devices such as crutches, battery-operated wheelchairs, pacemakers, and artificial limbs such as hands, arms, and legs. Mr. D told the class that artificial limb replacements are called prostheses and the process of making artificial limbs is known as prosthetics. Mr. D asked the class to think about the technology required to design and develop a prosthetic device for the loss of a hand. The students were then instructed to draw sketches or diagrams of prosthetic hands. The students shared and explained their drawings with the class.

The next day, Mr. D brought in some chopsticks and located various common items around the classroom. The objects Mr. D selected were a portable radio, a book, a pencil, the classroom TV, and a student's shoe. He asked each student to operate each object using only the chopsticks (i.e., turn on the radio, turn the book pages, or tie the shoe). The class then discussed the difficulty of performing these simple tasks with the chopsticks. Mr. D then asked the class how a prosthetic device might work under those conditions.

The students were then divided into smaller groups and asked to answer the following questions:

- How could a prosthetic device be connected to a person?
- What problems might occur in using a prosthetic device?
- How would a prosthetic arm be different from a prosthetic hand?
- What are the ways prosthetic devices have influenced society?

As a follow-up, Mr. D asked a local manufacturer of prosthetics to speak to the class and show several different types of prostheses. Some of the students went on the Internet and found a web site about the history of prosthetics.

Example modified from NASA Explores http://www.nasaexplores.com/index.php

Middle School (6th – 8th Grade)
The curriculum for medical technology at the middle school level should be organized to provide activity-based learning situations that help students explore and develop a broader perspective. Medical technology experiences can assist students in learning about the devices, processes, and knowledge sources. At this grade level, further development about the nature and evolution of medical technology will assist students in deepening their understanding of scientific and technological concepts, principles, and contexts. Students can begin to apply problem solving strategies, design concepts, and apply systems thinking to assess the impact and consequences of medical technology. Students should also be given the opportunity to see the relationship of medical technology to other fields of study. Sanitation, disease prevention, and medical technology advances with applications are all appropriate topics. Middle school students can design and engage in innovation activities related to medical products, systems, or procedures. They can learn to apply engineering, computer, and industrial design principles to medical technology. In addition, they can begin to form interests, discover talents, and develop skills related to medical technology.

Courtesy Sam Castro, Univ. of Wis.-Milwaukee *Research Profile Magazine*

Eighth grade students investigate the effect of energy from the sun being absorbed on the earth's various surfaces.

The materials and resources required would include the basic equipment used in a science or technology lab, but it might also include conceptual models that could be developed on paper or computers. Medical professionals, the Internet, and field trips to hospitals or clinics could also be utilized.

Medical technology at this grade level can be taught by interdisciplinary teams that include a science, mathematics, or technology teacher. Specific pre-service teacher training in medical technology should be part of a technology education curriculum and in-service training should be required.

6th-8th Grade Key Concepts

- Context: Relationships to other fields of study
- Relationships: Sanitation and prevention of disease
- Technologies: Advances and innovations in medical technology devices
- Applications: Applications of medical technology devices and procedures
- Social Impact: Assessment of impact and consequences (e.g., ethical and social concerns)
- Processes: Development of physical and conceptual models about medical technology
- Learning Approach: Experiential and active learning through exercises, guest speakers, and field trips
- Supplementary: Genetic engineering processes

6th-8th Vignette

This example presents an approach for developing an exercise in developing sanitation procedures for the prevention of disease. This example highlights a conceptual element of medical technology for grades 6-8 and is congruent with the International Technology Education Association (ITEA) *Standards for Technological Literacy*, Standard 14E, and the American Association for the Advancement of Science (AAAS) *Benchmarks for Science Literacy*, Benchmark 8F.

Students in Ms. G's seventh grade science class were reading about the great influenza epidemic of 1918. Ms. G asked the students to think of the last time that many students were out sick with colds or the flu. She began a class discussion about epidemics and public health by asking students to compare the health conditions at the turn of the 20th century with modern conditions in the 21st century. The students made a list of the similarities and the differences. They listed items such as access to medicine, ventilation, diet, and sanitation. "How," Ms. G asked, "do each of these factors contribute to the spread of illness?"

Next, the students were instructed to identify some of the technological improvements for the prevention and treatment of flu epidemics. The students brainstormed improvements identifying flu shots, new medicines, and healthy practices such as hand washing or the use of tissues. Ms. G asked the students to think about the factors at their school that caused colds and flu to spread quickly: crowded classrooms, shared lunchrooms, and winter conditions. Ms. G then instructed the students to list the preventive measures they would recommend to stop colds or flu from spreading. She reminded them that any public health measure would need to be considered carefully so as not to disrupt daily life or violate people's civil liberties.

Based on their list of recommendations, Ms. G assigned students to prepare informational posters on preventive measures and the various sanitation procedures. These posters were geared toward students, teachers, and administrators for the prevention of colds and flu. Ms. G was fortunate in that the timing of this lesson was just before flu season. Both the principal and school nurse suggested hanging the posters in various locations around the school to remind everyone about healthy and sanitary habits. As a result, the school had its best attendance record ever during the flu season.

Example modified from PBS Teacher Source http://www.pbs.org/teachersource/

Courtesy Argonne National Laboratory

Students watching a demonstration of high temperature superconductivity.

High School (9th – 12th Grade)
The curriculum for medical technology at the high school level should be organized to develop a richer and deeper understanding of the field and its relevance to career opportunities. The integration of, and contrasts between medical technology and other disciplines is appropriate at this grade level, especially where there is direct application. Extended laboratory exercises, hands-on experiences, and the application of scientific principles to medical technology issues are recommended. Students can also apply scientific principles, problem solving, and engineering methods in the solution of medical technology problems. Students could begin to explore the capabilities, uses, and consequences of medical technology in detail while employing resources to analyze the behavior of technology systems. Contrasts between medical technology and biomedical technology can be helpful as well as discussions on specific medical technologies such as telemedicine and hospital communication systems. The goal is for every student to graduate with a solid foundation in medical technology so they make informed choices regarding healthy lifestyles, participate in the debates regarding medical technology or can pursue a career in a technical field.

The materials and resources required include the equipment used in science and technology labs for the development of physical models along with higher levels of computerized conceptual models. Medical professionals, the Internet, medical textbooks, journal articles, and field trips are also recommended as resources.

Medical technology at grades 9-12 can be taught by interdisciplinary teams as part of a science, math, engineering, and technology curriculum. It can also be taught by specialized licensed science or technology education teachers. Specific pre-service teacher training in medical technology should be included as part of a technology and science education curriculum and in-service training should be required and periodically recertified.

9th-12th Grade Key Concepts

- Context: Relevance to career development
- Relationships: Medical technology versus biomedical technology
- Technologies: Telemedicine/hospital information and communications systems
- Applications: Application of scientific principles, problem-solving and analysis to medical technology issues
- Social Impact: Analysis of medical technologies capabilities, uses, and consequences
- Processes: Design, production, and use of medical technology
- Learning Approach: Hands-on experimental and laboratory learning
- Supplementary: Alternative and preventive medical techniques

9th-12th Vignette

This example develops a strategy for discussion and design of telemedicine and hospital information/communications systems. This example highlights a conceptual element of medical technology for grades 9-12 and is congruent with the International Technology Education Association (ITEA) *Standards for Technological Literacy*, Standard 14E, and the American Association for the Advancement of Science (AAAS) *Benchmarks for Science Literacy*, Benchmark 8F.

Two high school instructors decided to team teach a module on telemedicine to their 12th grade computer science and technology class. First, they asked students for their definition of telemedicine. After a brief discussion, the class agreed that telemedicine is a method that integrates telecommunications, computers, and medical technologies for the purpose of delivering health care.

The instructors then presented the class with a scenario. With the aging population, there is an increasing need for home health care. Elderly patients could avoid routine trips to the hospital or doctor by sending pictures, video or vital sign measures. The instructors then divided the students into teams and gave them the assignment to develop a telemedicine system for the home. A constraint was that the system had to be small enough to fit in a single room in a house. As part of the design, students were asked to develop the following:

- A list of items that a doctor might want to see or measure to determine a patient's health or the extent of an injury.
- A description of the components and equipment required for a personal telemedicine system.
- A conceptual diagram or sketch of the personal telemedicine system, including hardware and information flows at both the patient's home and the hospital or clinic.

Upon completion, the student teams presented their telemedicine designs to the rest of the class. Each team explained the operation of their system, gave an estimated cost, and answered questions regarding use and effectiveness. Students then engaged in a general discussion about the advantages and disadvantages of telemedicine. The instructors raised additional questions for group discussion and research. Some of the additional issues were:

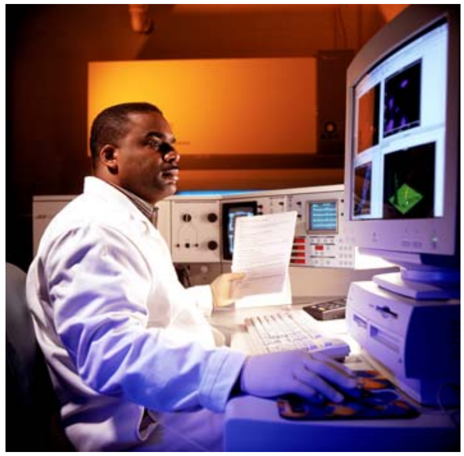
- The willingness of patients to use telemedicine instead of traveling to a clinic or hospital
- The use of telemedicine as a replacement for trips to the doctor or hospital.
- Should personal telemedicine system should be limited to homes? If not, how could it be used in school or business?

Some of the students did additional research on telemedicine and used the material for their final class project and paper.

Example modified from NASA Explores http://www.nasaexplores.com/index.php

Summary

The concepts presented on the previous pages assist students in developing an appreciation for the nature of medical technology. The context of medical technology provides a rational framework for study while the relationships define the interdependency of medical technology within each context. Medical technology consists of ideas from many different disciplines that are applied to specific issues. These technologies, usually in the form of devices or applications, are improved and change over time depending on the needs and wants of society.



Courtesy of GTEC

Information technology, computing power, and greater levels of magnification now allow medical scientists and technicians to see the detail of human cellular structures.

Science, technology, and society have a reciprocal relationship. Science affects technology and technology impacts society. Society, in turn, affects the development of both science and technology. Technology consists of processes used to advance the scientific pursuit of knowledge. If knowledge and science is the driver of technology, then technological processes are the catalyst for social change.

Each student learns and uses knowledge using different approaches. Certain approaches may be more appropriate at certain stages of development. Infants develop a keen sense of touch, growing into children who draw pictures, then into adolescents who accumulate language and mathematics skills. Thus, the learning approaches for the study of medical technology should be developmentally appropriate. In addition, supplementary information may be helpful in establishing a framework for learning medical technology. Table 1 summarizes these grade specific concepts within a matrix model. The first column of the matrix describes the conceptual educational standard while the other columns describe how the standard might be taught for that grade.

Conclusion

The content and context of medical technology in education is a growing field of study. Yet, there are many who remain unaware and uninformed about it. A recent International Technology Education Association/Gallup Poll survey (Dugger & Rose, 2002) asked over 1000 people about their attitude toward technology. The results of the survey indicated that many Americans view technology narrowly; they think primarily of computers and the Internet, rather than the ability of people to modify the natural world. While computers and the Internet are important parts of technology, they are not fully descriptive of the breadth of technological development. Technology is the practical application of scientific knowledge to in a particular area. Medical technology is the modification of the world through medical devices, procedures, and knowledge.

In the ever-changing world of technology, the development of scientific and technological literacy will assure that everyone can participate, live, and work productively to the full extent possible. The alternative is a regression back to fear, suspicion, and mistrust. The development of an economically viable health care system depends on the improvement of medical technology. Citizens who are literate in medical technology understand the limitations and possibilities of healthcare systems. Patients who understand the potential risks and rewards of a technology-based medical system are less likely to misuse it and are more likely to participate in making sound choices about it.

Table 1. Grade Level Key Concept Matrix

Grade Level *Key Concepts*	**3-5**	**6-8**	**9-12**
Context	Integration to other disciplines-e.g., math, science, social studies	Relationships to other fields of study-e.g., engineering, computers, design	Relevance to career development-e.g., doctors, nurses, medical technicians, service, repair, administration
Relationships	The use of medical products or systems to inform, heal or prevent disease-e.g., prevention of disease, body temperature	Sanitation and prevention of disease-e.g., vignette	Medical technology versus biomedical technology-e.g., x-ray vs. vaccines
Technologies	Devices that repair or restore body functions-e.g., vignette	Advances and innovations in medical technology devices-e.g., artificial hearts, hips, knees	Telemedicine/hospital information and communications systems-e.g., vignette
Applications	Application of common health devices and practices-e.g., toothbrushes, eyeglasses	Applications of medical technology devices and procedures-e.g., blood pressure gauge in grocery store	Application of scientific principles, problem-solving and analysis to medical technology issues-e.g., hip replacement CAD
Social Impact	Benefits of medical technology-e.g., restoration of functions for people with disabilities	Assessment of consequences, ethics, and social concerns-e.g., Karen Ann Quinlan	Analysis of capabilities, uses, and consequences-e.g., medical decisions, trade-offs
Processes	Construction of physical models-e.g., stethoscope, microscope	Development of physical and conceptual models-e.g., diffusion process	Design, production, and use of medical technology-e.g., cardiopulmonary resuscitation (CPR)
Learning Approach	Active learning with common medical devices-e.g., thermometer, sphygmomanometer	Experiential and active learning through exercises, guest speakers, and field trips-e.g., hospitals, device manufacturers	Hands-on experimental and laboratory learning-e.g., Internet research, cooperative education
Supplementary	The role of medical technology in healing-e.g., casts, splints, bandages	Genetic engineering processes-e.g., cell counts, lab procedures	Alternative and preventive medical techniques-e.g., acupuncture

Next Steps

The following is a suggested approach for teachers who are interested in incorporating the study of medical technology into their school program. First, in conjunction with state and district standards, pick the appropriate core concepts you want the students to master from your class or project. For example, one of the core concepts is that the study of medical technology requires the development of both science and technological literacy. Second, extract and organize the content taking into consideration the specific understandings required, prior knowledge, and connections to other required material. At this point, you may discover that you do not possess the required level of expertise in the content area so you will need to develop strategies for accumulating this knowledge through others or through personal research. Third, when you are comfortable with the content, you can begin to define the assessment criteria using matrices, rubrics, or other means. These assessment criteria are developed to provide the basis for capturing the essential ingredients of the content to be measured and indicate a student's level of medical technology literacy. Fourth, pick the key concept areas for the grade level that would best support the core concepts you have previously selected. For example, a middle school teacher may decide that the best way to develop both scientific and technological literacy is to demonstrate the application of a few medical technology devices and procedures. After selecting the key concepts, develop your plan for the curriculum, the units required, and the daily lessons, which might include exercises, guest speakers, or field trips. Finally, pilot test the course material, involve others in evaluating the content, and make adjustments based on the both student assessments and teacher evaluations. Table 2 summarizes the suggested steps for developing a medical technology curriculum.

Table 2.

Developing a Medical Technology Curriculum

Step	Activity
1	Select the appropriate medical technology core concepts
2	Extract and organize content
3	Define assessment criteria
4	Pick key concepts for the grade level and develop curriculum, units, and lesson plans
5	Pilot course material, evaluate, and adjust

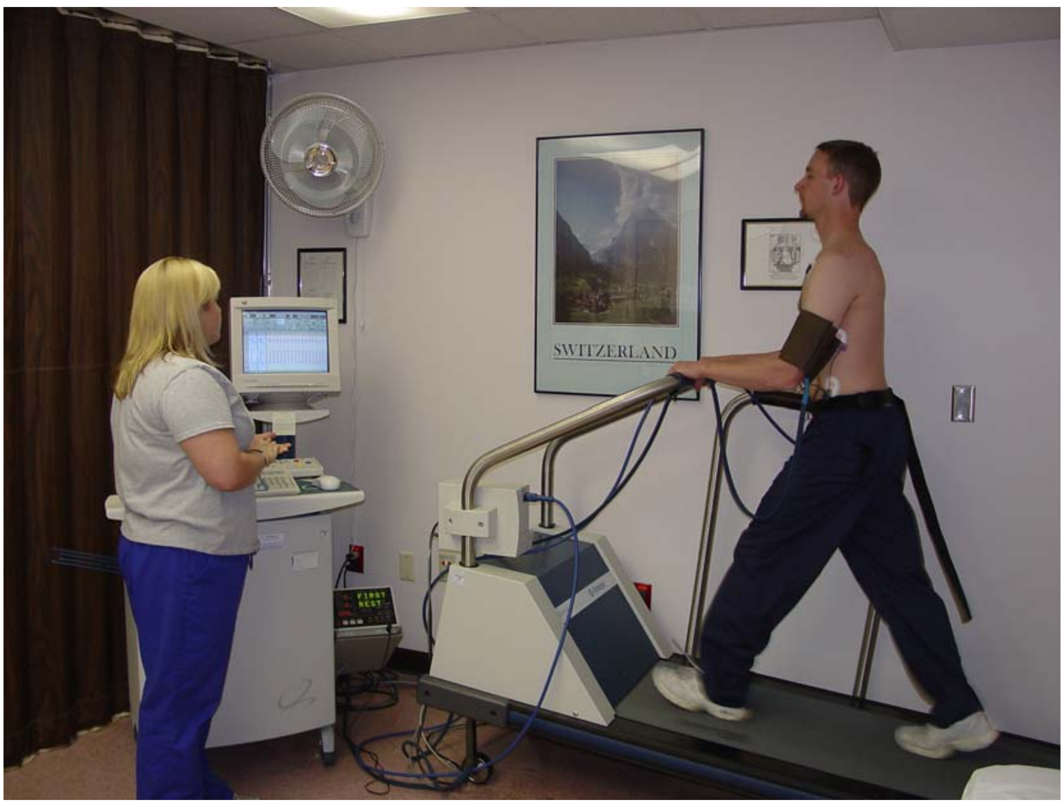
Courtesy Harmony Imaging Center

Medical technology requires knowledgeable professionals that can understand and operate complex equipment using precise procedures.

A Vision for the Future

The field of medical technology will need professionals who have the appropriate knowledge and expertise about diagnosis, treatment, and alternative methods. Local, state, and federal government decision makers will need to be informed about the applications and benefits of medical technologies so appropriate controls and regulations can be developed. Educational leaders will need to understand the impact of medical technology on society and how society perceives technology so that learning institutions and students can realize their full potential.

This vision must be shared by those who have a stake in the future of engineering, technology, and science education. This is not just teachers, but administrators, parents, medical professionals, and the general public. This document represents the beginning of an effort to expand and disseminate information that is becoming essential for student educational development. A greater understanding of medical technology and the education of medical technology must become a valued subject at every level.



Courtesy Poudre Valley Hospital

Cardiac stress tests assess heart performance prior to rehabilitative exercise therapy.

Section IV. Taxonomy, Framework and Context for the Study of Medical Technology

What will this section cover?
The development of a taxonomy for medical technology
Using the medical taxonomy
Integrating the taxonomy into the curriculum

What will this section help me understand and be able to do?
How the medical technology knowledge-base for science and technology were organized
Link the medical technology taxonomy to other technologies, i.e. energy forms
Integrate problem-solving and decision-making into a medical technology context

Taxonomy Framework and Context

Introduction

Health and education are vital issues for individuals and society, and relationships between health and education were recognized long before Congress created the Department of Health, Education and Welfare in 1953. Since that time, governmental agency names and responsibilities have changed, but the need for improved health care and education has only become greater. Many of the critical issues in both health care and education relate to access and knowledge (Altekruse & Rosser, 1992). The more individuals know about managing and taking responsibility for their own wellbeing and education, the greater their access to better health care and increased knowledge.

The access imperatives in health care and education coincide with a national trend toward an increased reliance upon technology. The International Technology Education Association (ITEA) addressed this issue in the *Standards for Technological Literacy: Content for the Study of Technology* (2000). This standards document asserts: "…technology is evolving at an extraordinary rate, with new technologies being created and existing technologies being improved and extended" (p. 2). Further, ITEA stated: "In a democratic society such as ours, individual citizens need to be able to make responsible, informed decisions about the development and use of… technologies" (p. 57). The expanding scope of technologies and ITEA's commitment to preparing students for life in a technological world led to the inclusion of a medical technology standard and benchmarks for learning.

The purposes of this paper are to describe how the content for medical technology was defined and organized into a taxonomy and to propose a decision model that students and teachers can use to assist them in making responsible and informed decisions about technology. The rapid changes in technology, pointed out by ITEA, can affect not only the decisions we make about technology, but also the way we think, the way we feel, and how we live our lives. It is important that we do not allow technology to shape our decisions and our lives, but that we apply our knowledge and understanding to the questions of how we will relate to technology. When we allow technology to shape our decisions, we relinquish our responsibility for making decisions. The ITEA standards document calls upon us all to make responsible *and* informed decisions.

Within the context of medical technology it is unrealistic to think that we can teach students today everything they will need to know tomorrow. If we teach students how to make informed and responsible decisions related to technology, when they are confronted with questions we have not anticipated, they will be prepared to resolve dilemmas and choose an appropriate course of action.

Medical Technology Standard

Standard 14 – "Students will develop an understanding of and be able to select and use medical technologies" (ITEA, 2000, p. 141).

Standard 14 in the *Standards for Technological Literacy: Content for the Study of Technology* (2000) proposes a new curricular context for technology studies in K-12 education. A project to define the content for this standard was undertaken by Zuga and Lewis, who proposed and received a National Science Foundation grant to support the present research. One of the objectives delineated in the grant was to use "…the new standards as the primary catalyst to create …professional development materials that would support the in-service needs of technology teachers" (Zuga & Lewis, 2001, p. 5). To address this objective, a taxonomy of medical technology content and a decision model have been created. The decision model is embedded within the medical technology curriculum report, so the two can be used together to enhance the study of medical technologies in K-12 education.

Standard 14 of the ITEA *Standards for Technological Literacy* inspired the decision model which is a part of the Technology Teacher In-Service Education (TTSE) project. The scope of the standard is quite broad and must be considered within the context of K-12 education. There are numerous medical technologies that only the most sophisticated experts understand and can use. Further, technologies are changing rapidly and the content of the field will be different tomorrow from what it is today. Hence, our job is to find a way to organize and present the field of medical technology in such a way that enables students to investigate the content and concepts and encourages teachers to facilitate that exploration.

Recognizing that we are limited in the quantity of content that can be included in the K-12 environment sets a boundary in one dimension. However, ITEA's further statement, "Individual citizens need to be able to make responsible, informed decisions about the development and use of…technologies" (p. 57), charges us to accept the greater challenge of addressing ethical issues and cultural values extending beyond the boundaries of content and context.

Technological Changes

Technology can shape the way we think, the way we feel, and the way we make decisions. Ursula Franklin wrote in her 1993 call for standards, "…recent advances in science and technology have increased the machinery of dominance and oppression" (p. 733). She identified significant ways that technology is threatening human rights, and we cannot ignore that our teaching about technology must include an examination of the implications of technology as well as its practice.

Franklin points out that technology can be particularly dangerous because while it maintains control, it also becomes invisible as we become accustomed to it. Surveillance technologies provide examples where fear and concern motivate us to welcome the protection and acquiesce to the invisible control. Supermarket savings cards might seem particularly benign. They allow us to save money when shopping on a daily basis and sometimes offer rewards for continued patronage. However, in exchange for the savings, we give away the privacy of our shopping habits. Can we be sure, for example, that a pattern of unhealthy food choices is not being shared with insurance companies which might monitor risk factors for health issues? Surveillance cameras in schools ostensibly provide protection from violence, but can also invade the privacy of students and teachers. We can confine the content of medical technology within boundaries for the purpose of defining context and setting rules for inclusion and exclusion; but we cannot and should not expect those boundaries to protect our human rights.

According to Neil Postman (1998), a critic of technology and chairman of the department of culture and communications at New York University, "…all technological change is a trade-off." He points out there are always consequences to technological developments; as something is given, something else is taken away. In reference to medical technology specifically, he says: "Medical technology brings wondrous cures, but is, at the same time, a demonstrable cause of certain diseases and disabilities, and has played a significant role in reducing the diagnostic skills of physicians" (1998, p. 2).

Rebecca Dresser (AWISCO, 2002), professor of law and ethics in medicine at Washington University in St. Louis, has written about ethics, science and medicine. Her comments about the need to "…strike a balance between improving medical procedures while managing the risks of experimental interventions" relate to ethical issues that confront us when we consider the intersection of medical technology and responsible and informed decisions. Dresser noted, "It seems that every step we take forward in science is also a step into the land of unexplained questions." The threats to human rights mentioned by Franklin are among these unexplained questions described by Dresser.

Dr. Ruth Hubbard, emerita professor of biology at Harvard, echoes the same concerns in her book, *Profitable Promises*. In writing about refined procedures for DNA testing, Hubbard stated: "I no longer need to demonstrate symptoms. If I have the DNA marker, I will be diagnosed as sick with the associated condition: invisible genes become one with visible traits" (Hubbard, 1995, p. 73). The implications of genetic testing are complex and further demonstrate Franklin's thesis, "Recent advances in science and technology have increased the machinery of dominance and oppression" (Franklin, 1993, p. 733).

These writers exhort us to consider the implications of technology. Whether we call the effects of technological procedures and practices side effects, secondary effects, or unintended effects, they are effects all the same. With so many issues to consider, and faced with new decisions about technology each day, the understandings students develop today about making informed and responsible decisions in the context of technology will be called upon to inform their choices as they confront the issues and questions of tomorrow.

The issues, concerns, and warnings discussed by Franklin, Postman, Hubbard, and others were considered by those working on the TTSE project. This report considers those concerns in relationship to Standard 14 and the K-12 curriculum. This paper represents my work on the project, which has progressed through three phases; investigation of language, conceptualization of a taxonomy for medical technology, and development of a decision model. Throughout these phases, I have focused specifically on the context of medical technology.

Importance of Language in Medical Technology

The term *medical technology* connotes a broad range of human-made machines, techniques, and procedures, all related to the practice of medicine and its allied disciplines. Indeed, the Appendix (ITEA, 2000, p. 213) to the standards document suggests a broad range of benchmark topics for inclusion, based on student grade levels. Some of those topics, such as *vaccines*, *medicines*, and *immunology* are directly related to Standard 14 and have been included in this organizational structure. Other benchmark topics appear to be more naturally related to content from other standards. For example, *use of systems to inform* is conceptually related to Standard 17, Information and Communication Technologies, and *genetic engineering*, shares both tools and techniques with Standard 15, Agriculture and Related Biotechnologies.

It might also be accurate to state that *medical technology* is an allied health profession that is practiced in laboratories and supports the operation of hospitals and medical facilities. However, this definition would exclude extra-institutional procedures, such as home testing of blood sugar, an increasingly common practice of persons with diabetes who have received specialized training allowing them to participate in their medical care (Blair, 2001).

Taken in the context of Standard 14, medical technology denotes the human-designed procedures and techniques carried out by individuals in maintaining, promoting, and restoring wellness. It is important to note that human bodies respond automatically in certain situations, thereby maintaining, promoting and restoring wellness. Examples of this would be the normal digestive process, or the naturally occurring formation of antibodies to fight infection. These processes are intentionally excluded from the definition of medical technology because men and women working to maintain, promote, or restore wellness of others did not design them.

The language of medical technology includes the terms we use to name artifacts, materials, and activities, the ways we communicate about procedures and processes, and the contexts for thinking about social meaning and practice (Ehn, 1989). Language facilitates meaning making and conveys values and beliefs; however, it is also dependent on context for meaning (Gergen, 1995). As a result, not only medical terms were of interest in this project, but also the contexts of the terms for the way in which they transmit meanings.

Papert's constuctionism suggests that constructivism understates the role of language in learning. In his writing about the use of technology as a tool in learning environments, Papert extended the constructivists' adage, "you learn better by doing," adding his own message, "[You learn better by doing], and best of all by thinking and talking about what you do" (1991, p. 42). Based on this reasoning, students will learn best about medical technology when they are given the opportunity to construct meanings based on their personal experiences and to interact and communicate with others about those understandings. Investigations begin with students selecting technologies to investigate that are within the context of their interest. Teachers guide students through discovery, and understanding develops as students *think and talk about what they do*.

This taxonomy for medical technology and the accompanying context evolved from the study of the language from the medical field. In essence, the terms were the data for the conceptualization of the taxonomy, the second phase of my involvement in this project. The taxonomy was designed to anticipate growth in the field. As new terminology emerges, students will be able to organize the concepts within the framework. *Kyphoplasty* is an example. It is a relatively new procedure that we did not find in our search for terms in September 2002. However, interventional radiologists are refining the techniques for this minimally invasive procedure, and as patients receive the benefits of this treatment for spinal injuries, students will be able to find the natural place for the term in the taxonomy. (MedicineNet.com (2004) defines *Kyphoplasty* as a therapeutic technology using inflatable balloons to reposition a crushed spinal column.)

Designing Taxonomies

Taxonomies are systems for organizing and classifying information according to similarities, differences, and attributes (McCarthy, 1995; Montague Institute Review, 2001). The purpose of this medical technology taxonomy is to situate the field of study within the broader context of technology education and to provide a structure of hierarchical relationships for decision making. “A good taxonomy helps decision makers see all the perspectives, ‘drill down’ to get details from each, and explore lateral relationships among them” (Montague Institute Review, 2001).

In this medical technology taxonomy, the basic units for organization are medical procedures and techniques. Blood tests and sonography would be examples. Machines, and supporting processes, such as centrifuge machines, global positioning systems, and communication pagers have not been included. The taxonomy is organized deductively with more general concepts toward the top of the system. The top-down approach allows the field of medical technology to be conceptualized within the context of technology education and supports integration of technology concepts within the larger framework presented by the ITEA standards document.

Within the field of technology education, there is historical precedent for organizing content according to taxonomic frameworks. The Industrial Arts Curriculum Project (IACP) generated *A Rationale and Structure for Industrial Arts Subject Matter* (Towers, Lux, & Ray, 1966) which included taxonomies for industrial technology and construction technology. The IACP arranged terms related to management, production, and materials in industrial and construction technologies according to their functional meanings. For example, in industrial production technology, *processing* was broken down into the more specific categories: *separating, combining*, and *forming* (Towers et al., 1966).

A 1984 report funded by the Technical Foundation of America, *Industry and Technology Education: A Guide for Developing Contemporary Industrial Arts/Technology Education Curricula* provides another example of a taxonomic framework. That report’s, Appendix C (Wright & Sterry, 1984) organized 242 terms according to their functional definitions. In Wright and Sterry’s example, *construction production processes* were divided into the following categories: *preparing the site*; *building the structure*; *installing utility systems*; *enclosing the structure*; etc. (p. 225).

Paul DeVore (1980) discussed taxonomic analysis related to technological systems in *Technology: An Introduction*. He wrote: “Taxonomic analysis is another way to classify the component elements of a system. A taxonomy orders elements according to a central theme, a hierarchy, and relationships” (p. 246). DeVore further stated that subsystems could be arranged on the basis of function, activity or problem category. The example he provided was for a taxonomy analyzing a transportation technology system.

While Towers et al. (1966) and Wright and Sterry (1984) emphasized activities and functions in their taxonomies, DeVore’s (1980) suggestion of organizing around problem categories sets forth an approach that is especially suited to a taxonomy of medical technology for K-12 education. Students exploring ways of solving problems in human body systems can use the taxonomic organization to work from generalized concepts and to discriminate between procedures as they gain new understanding about medical procedures, processes and techniques.

Taxonomic Content Levels

The proposed taxonomy of medical technology content (Figure 1), employs seven levels. Those levels, what each represents and includes are explained in the following sections.

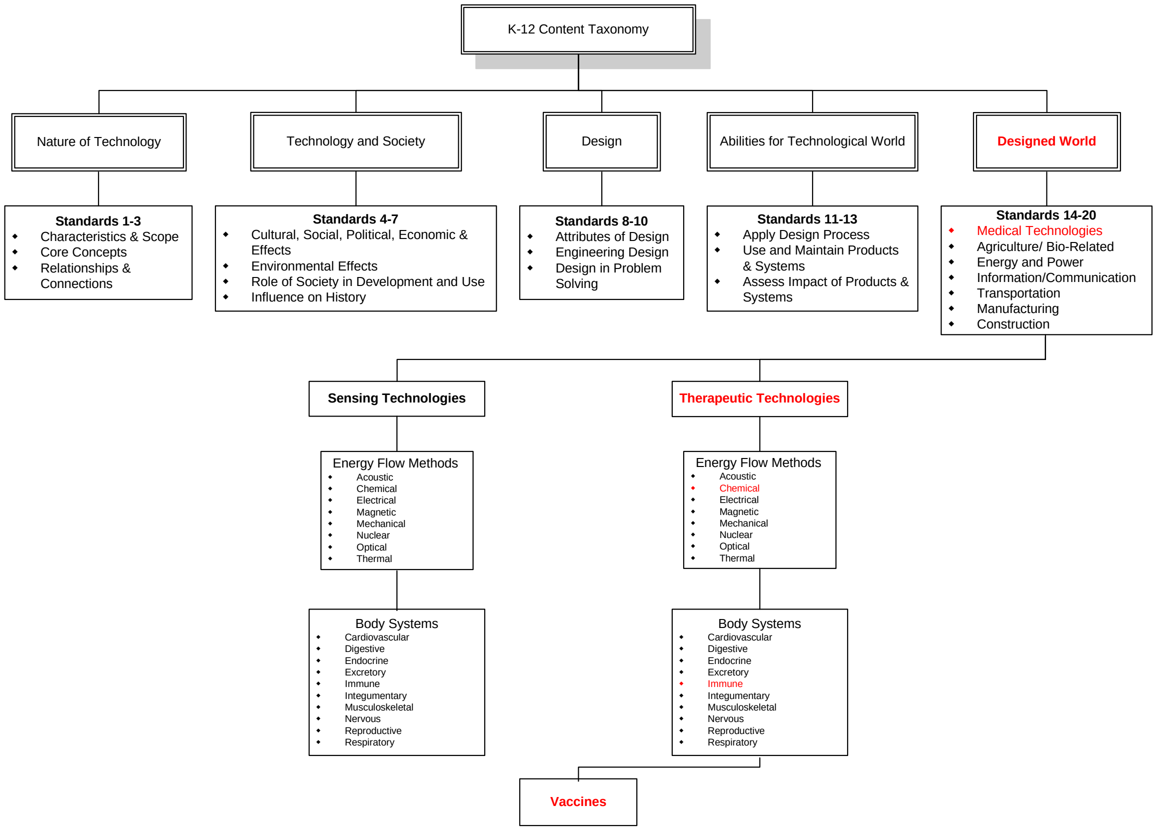


Figure 1. Medical Technology Taxonomy

Level I – Field

This level represents the field of technology education as it has been set out by ITEA in the standards document. The content included in the *Standards for Technological Literacy* (2000) comprises that knowledge which all students are encouraged to master as they develop the abilities necessary "…to use, manage, assess, and understand technology" (ITEA, 2003, p. 2).

Level II – Elements

The elements of technology education were conceptualized by ITEA and include the following five categories: *Students will develop an understanding of The Nature of Technology; Students will develop an understanding of Technology and Society; Students will develop an understanding of Design; Students will develop abilities for a Technological World; Students will develop an understanding of The*

Designed World. Each of these elements corresponds to a chapter in the standards document (ITEA, 2000, p. 15).

Level III – Standards

The twenty ITEA standards are organized into five categories which are listed under *Elements*. Standard 14, selecting and using medical technologies, is part of the Designed World. The implication of this placement for the taxonomy is that everything included in the lower levels is necessarily also part of the designed world. As a consequence, a naturally occurring medical event is not included in the taxonomy. The naturally occurring process by which wounds heal would be an example of such an event that is not included.

Level IV – Purpose

The purposes of medical technologies are divided into two categories by determining whether they are used for diagnosis or used for treatment of problems. The technology categories that are used as organizers are *sensing* and *therapeutic*. The health and medicine fields also include categories such as prevention, rehabilitation, and surgery; however these are not medical technologies according to the definition proposed for this taxonomy. As it was defined earlier, medical technology is the human-designed procedures and techniques carried out by individuals in maintaining, promoting, and restoring wellness.

In the practice of medicine and in the process of maintaining, promoting and restoring wellness to the human body, there is a cycling between evaluative and therapeutic technologies. The process begins with measurement of human functions; health care workers make decisions about diagnoses and therapies; treatments are followed; and finally, the process returns to measurement of function in order to assess the improvement in functions.

Writers from the field of science and engineering assert that there is an identifiable discipline known as “Sensor Science.” The article, *Sensor Science – Essentials for Instrumentation and Measurement Technology*, states: “Applying Classical Taxonomy to ordering Sensor Science is … shown to depend upon the cardinal link between humans and machines. This provides a context for describing the information flow interfaces between humans, machines and their universal environment” (McGhee, Henderson, & Sydenham, 1999, p. 89). Based on this rationale, the medical technology taxonomy includes the category of sensing technologies, as sensing also is based upon the link between humans and machines, procedures, and techniques. The purpose of diagnostic medical technologies is to sense and measure human functions.

All of the procedures, whether they are part of the diagnostic or treatment phases, are based upon forms of energy. The categories, *sensing* and *therapeutic* represent the different purposes of the procedures.

Level V – Energy Forms

Hutchinson and Karsnitz (1997), authors of the technology textbook, *Design and Problem Solving*, identified energy processing as a basic element in technological systems. While we identify energy forms as being essential to the processes in medical technology, Hutchinson and Karsnitz took a more conservative approach, and indicated that energy was a *possible* input to technological systems.

In the medical technology taxonomy at the energy forms level, sensing and therapeutic technologies are divided into categories based on energy forms. According to the McGhee et al. (1999), classification of sensors has been an ongoing effort for more than thirty years. The eight categories, which those authors recommended, were borrowed for this medical technology taxonomy. The eight categories are: acoustic; chemical; electrical; magnetic; mechanical; nuclear; optical; thermal. While these eight categories are shown as separate entities, in a majority of situations, multiple energy forms are used in combination.

These categories were tested, medical procedures were examined, and after extended investigation, medical technology procedures and techniques were found to fit within this classification scheme. Examples of all eight follow: ultrasound procedures use acoustic energy for sensing; vaccines use chemical energy for therapeutic purposes; MRI (magnetic resonance imaging) studies are based upon magnetic energy that creates images of structures in the body; resistance exercise, a therapy, is powered by mechanical and chemical energy; positron emission tomography (PET) combines nuclear scanning with chemical analysis for measurement; endoscopes rely upon optical and electrical processes; thermometers depend upon thermal energy when measuring body temperature.

The complexities of energy forms at this level of the taxonomy will require students to actively research the procedures they are investigating. The energy forms involved in even common medical procedures, such as X-rays, are actually quite complex. However, modern information technology provides a wealth of resources. As an example in the case of X rays, The Ohio State University Department of Extension Research has posted numerous fact sheets related to radiation on its Internet site. X-rays are explained in "What is Ionizing Radiation" (Fentiman, Leet, & Veley, n.d.).

Level VI – Body Systems

Linking technology with the human body is the essence of medical technology, and in order to emphasize the importance of the relationship between technology and the human body, *body systems* are placed below *energy forms* in the taxonomic hierarchy. Health and medicine reference materials used in researching medical technology routinely categorized the human body according to body systems (Ettinger & Burch, 1999; Insel & Roth, 2002); however, there is not a uniform method of categorizing the human body into systems (American Medical Association, 2003; Bailey, 2003; McGann, 2003; Medem, 2003; Spitzer & Whitlock, 1998).

Bailey (2003), in her article, *What You Need To Know About Biology*, categorizes the human body according to organ systems differentiated by functional processes. After examining numerous classification systems, Bailey's method was chosen for inclusion in the taxonomy because it is logical and readily available to students through the Internet. The systems are: circulatory, digestive, endocrine, integumentary, muscular, nervous, reproductive, respiratory, skeletal, and urinary. As is the case with energy forms, these organ systems may operate synchronously as well as in isolation. The human body is an integrated system "…made up of several organ systems that work together as one unit" (Bailey, 2003, ¶ 1).

Level VII – Applications

Procedures and techniques define the scope and nature of medical technology. The example, *vaccines*, shown in Figure 1 illustrates how the taxonomy can be applied. Students can begin their explorations into medical technology with a procedure that is known to them. To illustrate, a student may demonstrate an interest in Sickle Cell Anemia and research medical procedures related to this condition. According to the Sickle Cell Information Center at Emory School of Medicine (2002), "A simple blood test called the hemoglobin electrophoresis can be done by your doctor or local sickle cell foundation. This test will tell if you are a carrier of the sickle cell trait or if you have the disease." Further research could lead the student to the organ systems and organs affected by the disease, the energy forms used in measuring and treating the condition, comparisons with other types of anemia, and the decisions to be made by those who have Sickle Cell Anemia.

Integrating the Taxonomy into the Curriculum

Purposeful integration of curriculum topics promotes the development of problem-solving and decision-making skills, and also assists students in organizing their cognitive structures. Frameworks demonstrating connections between the concepts and relationships between ideas help students network their thinking processes and store information in their memories in an organized way. This concept was discussed in *Organization of Memory* by Collins and Quillian who stated: “How information is put into memory obviously has much to do with how it can be retrieved” (Collins & Quillian, 1972, p. 341.

Decision making and problem solving are important abilities for students to develop, and it would be most instructional if the teaching methods were synchronized with these goals. The taxonomic structure suggests connections and relationships within and between topics of instruction. Students can adopt and use that scaffolding while developing unique networks within their own memories.

An example of this transfer of learning can be seen in the case of students who already have an understanding of automotive repair methods using computers to diagnose problems. The application of energy as a sensing technology to diagnose internal problems in automobiles can be transferred to the field of medical technology where energy also is used in sensing technologies to extend first-hand observations and learn about problems in human body systems that are otherwise not discernable. This example of using sensing technologies to diagnose automobiles, from transportation technology, and human body systems, from medical technologies, illustrates a lateral relationship between technologies.

In addition to lateral relationships in the medical technology taxonomy, seven levels are arranged according to a hierarchy of generality, with the most general category at the top. Medical technology enters the structure at the third level, and the lower levels, four through seven, are key to defining the scope and nature of medical technology.

Using the Medical Technology Taxonomy

Kindergarten -12 students have different levels of awareness about medical procedures and will naturally be engaged in solving different problems. The Application Level (Level VII) in the taxonomy is intentionally designed to encourage teachers to create a stimulating environment where students at different stages of development and interest in a diverse range of topics can explore the processes from the entry points at which they have the most interest. An example of this would be high school students deciding to investigate ultrasound techniques they have read about in physics classes, and grade school children choosing to learn more basic concepts such as measuring heart rates while exercising. Both examples demonstrate the use of acoustic energy; ultrasound uses sound waves to image structures in the body, and stethoscopes amplify sounds of the heart and lungs.

Although the taxonomy is proposed primarily for use by teacher educators and in-service teachers, the example of acoustic energy illustrates ways students might also benefit from working with the taxonomy. Students and teachers will see how medical technology fits within the broader scope of technology education, how medical technology relates to the study of energy, and how medical technology has different applications depending on which human body system is being investigated.

Problem Solving

Problem solving effectively engages students in learning and is used frequently in primary and secondary education. In teaching problem-solving methods, means-end analysis is a well-known heuristic (Ashcroft, 1998). The medical technology taxonomy lends itself to applications of this method. Ashcroft (1998, p. 402) wrote in his book, *Fundamentals of Cognition*, "In this approach, the problem is solved by repeatedly determining the difference between the current state and goal or subgoal state, then finding and applying an operator that reduces this difference." Ashcroft's explanation of the heuristic can be applied to the taxonomy and students can solve problems by making decisions about goals and subgoals as they work through the discriminating levels in the taxonomy. As an example, if the problem of interest were ankle pain, this condition might be diagnosed using sensing technologies, perhaps magnetic resonance imaging, to view the patient's musculoskeletal system and determine if a bone has been broken or tendons have been damaged.

In *Everyday Cognition* (1999), Rogoff speaks to the relationship between problem solving and context. She points out that concepts developed within a context are generalized for use in other contexts. This point is important when we consider the many contexts for study within technology education specifically and general education more broadly. Rogoff's reasoning suggests that what students learn in the context of medical technology can be applied in other problem-solving contexts or vice versa. The student who has learned in an introductory technology class about laminating as a way to strengthen materials in a bridge-building project should be able to generalize the concept and apply the problem-solving procedure when she confronts the question of strengthening broken bones. Grafting procedures in agricultural and medical contexts share theoretical elements with lamination in the context of construction technology.

Considering how one might repair a broken bone or strengthen a bridge bed are both examples of problem-solving exercises that could be found in the literature about technology education. Often the terms *problem solving* and *decision making* are used interchangeably, and a distinction becomes important as I begin to explain the third phase of my involvement in the TTSE project. Here a model for decision making in the context of medical technology is developed. The distinction between problem solving and decision making is explicated by Kushniruk (2001, p. 367), who analyzes complex decision-making processes in health care. He states: "…decision making can be considered a problem-solving process in which the solution is in the form of a decision, typically leading to action." Applying this distinction to the earlier example of grafting demonstrates that repairing a broken bone is a *problem-solving* process, choosing grafting as the best approach for repair is *decision making*, a solution leading to action.

Decision Making

Problem-solving and decision-making skills are essential to technological literacy (ITEA, 2000). Being able to solve problems within specific contexts, leads to students' understanding of how to make informed decisions. It is our goal that students will learn to transfer their knowledge and skills from one context to another and become responsible decision makers. This transfer of learning can be encouraged through integrating concepts and subjects within a curriculum. Freeman, Field, and Dyrenfurth (2001, p. 62) described, "…a viable industrial technology strategy for employing contextual learning to build cross-functional skills." These authors cited the importance of students developing cross-functional skills in order to be equipped to transfer their learning to different contexts and solve real-world problems. To this, I would add that the success of the problem solution is only as strong as the underlying decisions.

Purposes for the Decision Model

When Gradwell (1999) juxtaposes the immensity of technology and the role of the individual, he highlights the importance of individuals in society being equipped to make responsible decisions. He emphasizes the role of values in decision making and cautions technology educators that in "…emphasizing the technical aspects of industry, or the techniques of making a product, social concerns, values or cultural influences [are] rarely included, under the consuming weight of purely technical information" (p. 243).

Postman's (1998) concerns noted earlier are echoed by Gradwell who states: "…each new technology does not simply add something to its environment: it fundamentally changes everything" (Gradwell, 1999, p. 244). Like Dresser (2002), Gradwell discusses the significance of balance in technology among responsibilities, resources, and expression (1999, p. 251). In his diagram, (Figure 2), *responsibilities* represent values and ethics, and contribute equally with resources and expressions in technological decisions. He suggests that "…a particular inquiry could start from any of the three points and progress to the others, ensuring that social relevance and ethical decisions are always a controlling factor" (p. 251). With this model and the accompanying text, Gradwell conceptualizes a way we might represent the integration of technologies within society and culture.

Gradwell reminds his readers that DeVore (1980) suggested that technologies be evaluated based on societal purpose rather than primarily on efficiency. While our responsibility to consider the effects of technology has been pointed out on occasion by other writers, the idea needs to be reiterated and brought to the forefront for students.

Integrating Decision Making within Technology Contexts

ITEA (2000, p. 7) addressed the issue of an integrated curriculum: "As envisioned by the standards…the study of technology is a way to apply and integrate knowledge from many other subject areas – not just mathematics, science, and computer classes, but also the liberal and fine arts." The medical technology taxonomy presents opportunities for combining the study not only of science and technology-related subjects, but also of the liberal and fine arts. The imaging techniques that are essential to many of the sensing technologies carry over into the area of fine art, with drawing and photography as two examples. Understanding the relationship between technology and society, the ethical responsibilities of individuals, and the economic implications related to medical technology can be explored in social studies classes. Bush (1983, p. 156), in her writing about the assessment of technology, proposed important questions for consideration: "…Who is making technological decisions?, on what basis?, what will the effects be?"

Decision Models

Decision models in the literature, applicable to the technology contexts range from references to Ben Franklin's *What Do I Do?* decision maker to examples in technology education textbooks to a complicated model from the journal, *Decision Science.* Franklin's method was to make a pair of lists representing pros and cons for a dilemma. He believed that working on the lists over a period of days helped him gain perspective on the decision, and careful evaluation of the list made him less likely to make mistakes in deciding what to do in a given situation (Prosavac & Carey, 1989). The method has a later iteration known as Multiple-Attribute Utility Theory (MAUT) which is used in the fields of business and needs assessment (Altschuld & Witkin, 2000). The simplicity of Franklin's method might make it appropriate for use with young children.

The systems model proposed by Hutchinson and Karsnitz (1997) is not exactly a decision model; however, the authors suggests in the text with the model that problem solutions "often take the form of systems" (p. 5). Their model shows a feed-back loop and includes inputs, processes, and outputs as the main elements. The inputs are listed as people, energy, capital, tools/machines, materials and information. The systems idea for problem solving is often criticized for including people as inputs, and therefore parts of systems (S.K. Damarin, personal communication, February 19, 2003). This criticism reflects the idea that people *use* systems, whereas if people were part of systems they would be in the position of being *used* themselves.

Hutchinson and Karsnitz also discuss technological dilemmas in their book and offer a "…five-step process to analyze the ethical dilemma created by technological activity" (1997, p. 16). These authors are to be commended for including this section and for their discussion of outputs that categorizes combinations of desirability and expectation for various system outputs. Their treatment of important issues avoids responsibility for decision making in suggesting that "…all systems produce wanted and unwanted outputs" (p. 8). Ethics appears a category for evaluation in their attribute matrix; however this later section concentrates on design solutions and does not relate individual or societal responsibility to the effects of technology.

Jackson, Kloeber, Ralston, and Deckro (1999) proposed a more complicated model in their article discussing the US Department of Energy's decision criteria for waste-site remediation. These authors suggest that their proposed model could be used as "a generic technology selection tool that can be used to make better informed decisions" (p. 217). Unfortunately for all of us in society, the values being considered in decision making about waste site remediation are: capital costs, research and development costs, time to full productivity, compatibility with other existing or innovative technologies, and risk of successful implementation. Perhaps these elements are adequate for "better informed decisions," but they do not meet the ITEA standard for making responsible, informed decisions. This model and others privilege efficiency over responsibility.

The model proposed here for decision-making within the contexts of technology and the context of technologies reflects the significance of language, and thereby culture, and ethics. The boundaries are fluid as they are in real-world situations, and the decision-making realms move in and out and between contexts; however, it also allows for the way that contexts occasionally overlap and impinge on one another. The model is iterative; constraints and resources are constantly changing while the decision making process is repeated, mirroring the way decisions reoccur and compete within our environments. Regardless of the number, shape or magnitude of decision contexts with which we deal, language and ethics extend beyond the boundaries of contexts guiding the decisions we make and the ways we use technology.

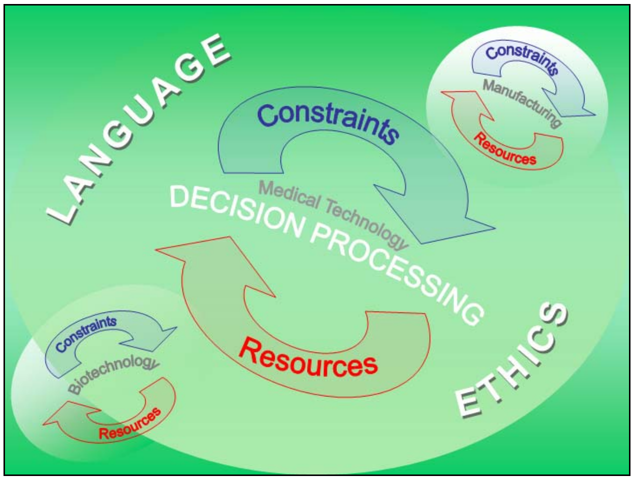


Figure 2. Decision Model

The decision model was developed based on research about decision making and observations of technology education students in decision-making situations. The components for the model, constraints, resources, context, language, and ethics emerged from a literature review. Observations of students demonstrated how the elements interact in decision-making processes. As this model has been configured, it is differentiated from others in that it recognizes the importance of language and ethics and the commingling of elements in the process.

Red, green, and blue were chosen purposefully to represent the model visually. Additive color theory explains that white light is a combination of red, green, and blue. Thus, the combining of these three colors to render white light in the model represents the coalescing of factors in the decision-making process.

The blue stylized arrow represents constraints on the decision making process, which "…alter the premises on which decision makers act" and include "…mental models held by the decision maker…Mental models house an individual's knowledge, experiences, biases, values, and beliefs about how the world works" (Swanson, 2003, p. 379). Kushniruk's (2001) analysis of complex decision making pointed out further that the expertise of the decision maker operates as a constraining factor on the process as well.

Resources include elements such as energy, materials, information, capital; all of which Hutchinson and Karsnitz (1997) identified as *inputs* to their system model. Resources function more externally than constraints on the decision maker. Considering the context of medical technology, resources would represent new knowledge acquired by students as they investigate topics and carry out their investigations.

From observations of students engaged in problem-solving and decision-making activities, it seems that the decision model represents decision processing more accurately then the linear processes suggested in the literature. This is not to suggest that students who are made aware of the model will necessarily make better decisions. The hope is that in encouraging them to become more aware of the process, they will consider the effects and consequences of technology more astutely.

As new technologies are aggressively developed, we are at risk of allowing technology to shape our decisions. If we do, we relinquish our responsibility for making decisions. The ITEA standards document calls upon us all to make responsible *and* informed decisions. Particularly within the context of medical technology, it is unrealistic to think we can teach students today everything they will need to know tomorrow. Today we can acquaint students with models for making informed and responsible decisions so that when they are confronted with questions we cannot anticipate, they will be prepared to resolve those dilemmas and to choose a course of action.

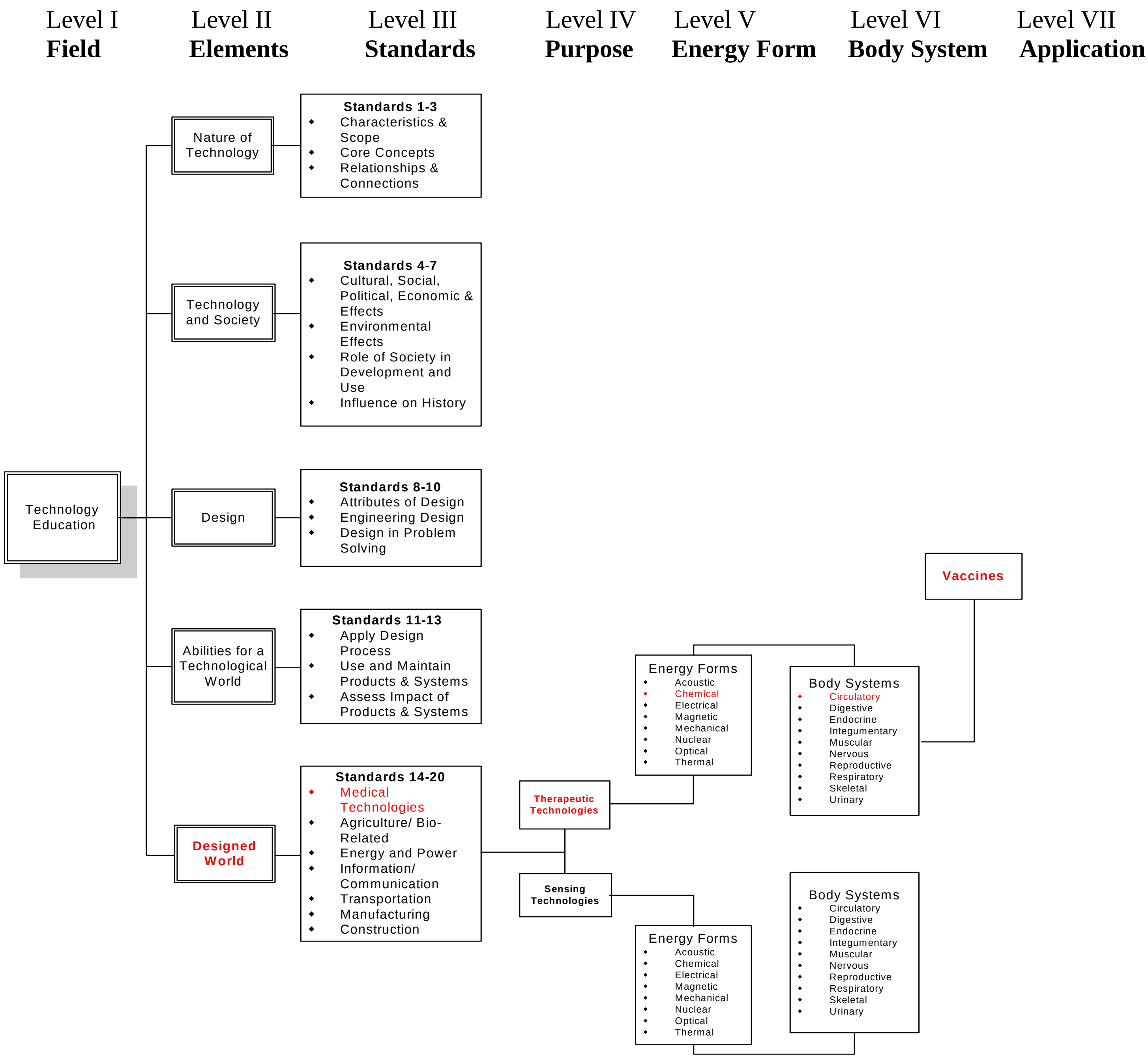
Conclusion

The three most important features of the medical technology taxonomy and decision model are that together they integrate technology with other disciplines (health, biology and engineering), offer students a framework for learning and practicing decision-making skills, and present a way to approach content for study in K-12 education.

ITEA has recognized that education in the 21st century is moving toward integration of disciplines and interdisciplinary approaches to teaching skills for a global society. “Understanding the symbiotic relationships between technology and science, mathematics, social studies, language arts, and other content areas is vital for the future” (ITEA, 2003, p. 15). Teacher educators and in-service teachers deserve to be prepared for this reality.

With increased emphasis on individual responsibility for making informed decisions and greater awareness of the need for solving world problems, an integrated approach to teaching technology is especially important. Working with the medical technology taxonomy and decision model, students and teachers can learn together about making responsible choices and rational decisions.

Figure 1. (Addendum) Medical Technology Taxonomy



Section V. Reference Material

What will this section cover?
List of references
Web-based resources
Contact information

What will this section help me understand and be able to do?
Identify published resources
Link to important medical technology web sites
Learn the key authors and contacts in the field of medical technology

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Medical Technology Web Resources

Commercial
Canada's Medical Device Technology Companies http://www.medec.org/
Medical Information Technology Systems, Inc. http://www.mitsi.org/
Medtronic (commercial medical technology company) http://www.medtronic.com/
Applied Medical Technology, Inc. (commercial medical technology company) http://www.appliedmedical.net/

Government
United States National Library of Medicine http://www.nlm.nih.gov
U.S. Food and Drug Administration (FDA) http://www.fda.gov/
National Institutes of Health (NIH) http://www.nih.gov/
Department of Health and Human Services http://www.hhs.gov/
Centers for Disease Control and Prevention (CDC) http://www.cdc.gov/
National Institute of Standards and Technology, Health Care http://www.nist.gov/public_affairs/healthcare.htm
National Center for Health Statistics (NCHS) http://www.cdc.gov/nchs/
Veterans Affairs Health Benefits and Services http://www.appc1.va.gov/Health_Benefits/
Bureau of Labor Statistics http://www.bls.gov/

Professional and Industry Organizations
Advanced Medical Technology Association (AVA Med) http://www.advamed.org/
American Hospital Association (AHA) http://www.hospitalconnect.com/
Engineering in Medicine and Biology Society (EMB) http://www.eng.unsw.edu.au/embs/index.html
American Public Health Association http://www.apha.org/
American Society for Testing and Materials (ASTM) http://www.astm.org/
Association for the Advancement of Medical Instrumentation http://www.aami.org/
Rehabilitation Engineering and Assistive Technology Society of North America http://www.resna.org/
The European Medical Technology Industry Association http://www.eucomed.be.
Medical Technology & Practice Patterns Institute http://www.mtppi.org/
Medical Technology Leadership Forum http://www.mtlf.org/
Medical Device Manufacturers Association http://www.medicaldevices.org/public/default.asp
Center for Integration of Medicine & Innovative Technology http://www.cimit.org/index.html
Computer Integrated Surgical Systems and Technology http://www.cisst.org/
American Society for Clinical Pathology http://www.ascp.org/
Clinical Laboratory Management Association http://www.clma.org/
American Society for Clinical Laboratory Science http://www.ascls.org/
International Technology Education Association http://iteawww.org/

Educational
ACT's World-of-Work Map Career: Area Q Medical Technology http://www.act.org/wwm/wow/career_q.html
Medical Dictionary Online http://www.online-medical-dictionary.org/
National Library of Medicine (NLM) http://www.nlm.nih.gov/
Medical Technology and Practice Patterns Institute (MMPPI) http://www.mtppi.org/
NASA Explores http://www.nasaexplores.com
PBS Teacher Source http://www.pbs.org/teachersource/

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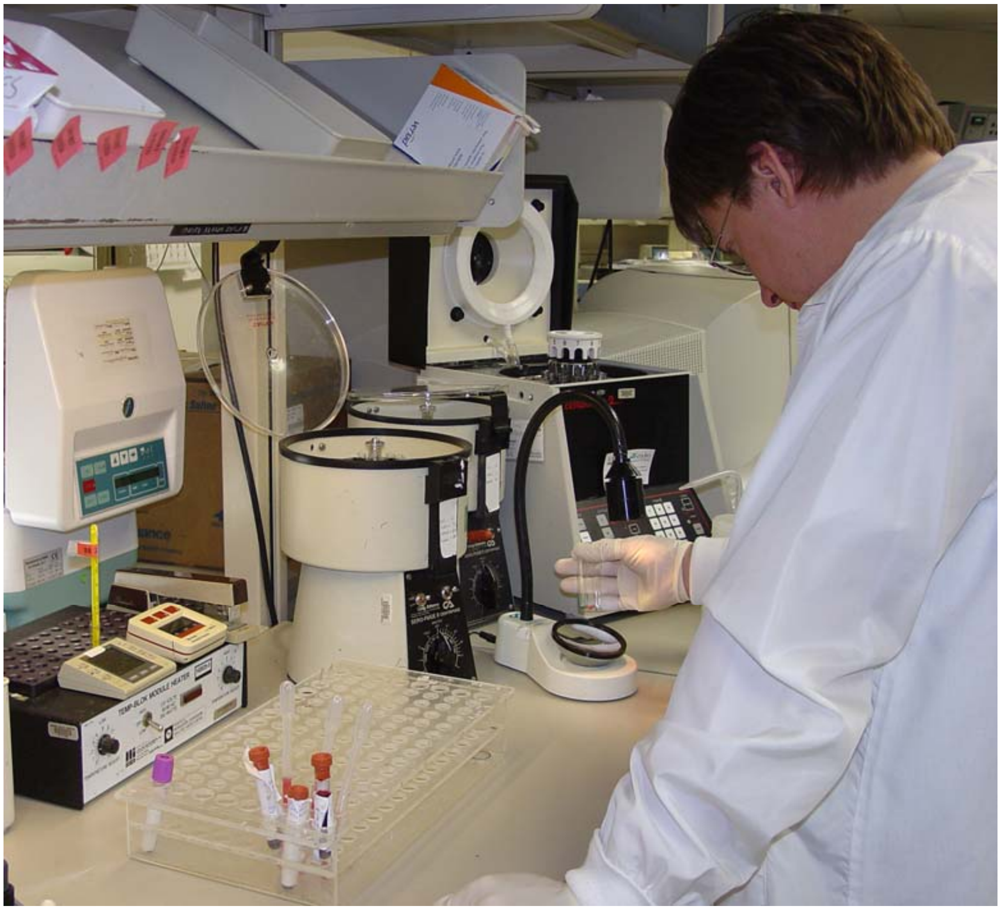

Courtesy Poudre Valley Hospital

Medical technicians observe, analyze, and
make decisions using problem-solving skills.

Courtesy Harmony Imaging Center

Detailed high-resolution picture of a
fetus using ultrasound technology.

Glossary of Terms

AIDS: Acquired immunodeficiency syndrome, a disease in which the immune system is weakened and therefore less able to fight certain infections and diseases; AIDS is caused by infection with the human immunodeficiency virus (HIV).
ALS: Amyotrophic lateral sclerosis, a thickening of tissue in the motor tracts of the lateral columns and anterior horns of the spinal cord; results in progressive muscle atrophy that starts in the limbs.
Anemia: A condition characterized by oxygen carrying deficiency caused by a low amount of red blood cells, iron deficiency, or sickle cell formation of red blood cells.
Anesthesia: Drugs that a person gets before and during surgery so he or she will not feel pain.
Appendectomy: The surgical removal of the appendix (to treat acute appendicitis).
Arthroscopic surgery: A surgical procedure of making small incisions, inserting tubes with fiber optics, and either diagnosing or repairing damage using cameras, lasers, or small tools inserted through the tubes.
Artificial intelligence: The field devoted to developing hardware and software that enable a computer to exhibit `intelligence' as defined and recognized by a consensus of human beings.
Biology: The science that studies living organisms.
Biomedicine: The branch of medical science that applies biological and physiological principles to clinical practice.
Cadaver: A term generally applied to a dead human body preserved for anatomical study. An individual who has recently died and his or her organs are given for transplantation.
Cancer: The name given to a group of diseases that can occur in any organ of the body, and which all involve abnormal or uncontrolled growth of cells.
Cannula: A small tube inserted into an artery or vein.
Cardiology: The study of the heart and its functions in health and disease.
Cardiovascular: The function pertaining to the utilization of oxygen by the body through use of the heart, lungs and the circulatory system.
Catheterization: The process of examining any part of the body by introducing a thin tube (catheter) into a vein or artery and passing it into the area being studied (i.e. the heart).
Centrifuge: A machine that rotates (spins) rapidly and uses centrifugal force to separate substances of different densities.
Chiropractics: A system of treatment based on the manipulation of the spinal vertebrae, the misalignment of which is believed to be responsible for pain and illness.
Clinical scientist: A person with advanced knowledge of one of more sciences who performs clinical research through the study, observation and treatment of patients.
CPR: Cardiopulmonary resuscitation; a first-aid method to restore breathing and heart action through mouth-to-mouth breathing and chest compression.
CT scan: Computed tomography scan. A series of detailed pictures of areas inside the body; the pictures are created by a computer linked to an x-ray machine; also called computed axial tomography (CAT) scan.
Diabetes: A disease where insulin, a hormone produced in the pancreas, does not transport glucose effectively from the bloodstream. Diabetics have to inject insulin so that the body can get enough glucose.
Diagnostics: The branch of medical science dealing with the classification of disease and the process of identifying or determining the nature and circumstances of an existing condition.
Diphtheria: An acute contagious infection caused by the bacterium Corynebacterium diphtheriae; marked by the formation of a false membrane in the throat and other air passages causing difficulty in breathing.
DNA: Abbreviation for deoxyribonucleic acid. DNA molecules carry the genetic information necessary for the organization and functioning of most living cells and control the inheritance of characteristics.
Electrocardiograph: A medical instrument that records electric currents associated with contractions of the heart.
Electroencephalogram: A procedure that records the brain's continuous, electrical activity by means of electrodes attached to the scalp.
Electromechanical device: The term given to a device that incorporates both electrical and mechanical features.
Electron microscope: An instrument that uses electrons, instead of light, to produce a magnified image of an object. The magnification that can be achieved is about one thousand times that of a light microscope.
Emergency medical technician (EMT): An individual trained to render immediate basic life support to ill and injured individuals, under the direction of a physician, and to safely transport them in a monitored environment to health care facilities.
Endocrine: The physiology of internally secreting glands.

Endoscope: A medical device for viewing internal portions of the body. It is usually comprised of fiber optic tubes and video display instruments.
Exercise therapies: Preventive health care that complements other forms of medical interventions. Examples include yoga, tai chi, bicycling, swimming, dancing, aerobics, weights, etc.
Flu: An acute infectious, epidemic disease marked by depression, fever, inflammation of the nose, larynx and bronchi along with muscular pains; caused by a virus; also referred to as "influenza".
Fluorescent: The quality of having the ability to emit light when struck by electrons or another form of radiation.
Forceps: A pliers-like tool that locks closed; also called "hemostats."
General practitioner: A physician whose practice is based on a broad understanding of all illnesses and who does not restrict his/her practice to any particular field of medicine.
Genetic engineering: A way of directly manipulating genetic material in a cell or organism to produce desired traits/ characteristics and eliminate undesirable ones.
Heart-Lung bypass machine: A device that takes over the function of the heart and lungs during heart surgery allowing the heart to be stopped and repaired.
Holistic medicine: Therapies based upon holistic principles recognize that each person is an individual and attempt to treat the whole person - body, mind and spirit.
Homeopathic remedies: The applications of small doses of medicines, herbs, or both that are believed to stimulate the immune system.
Immunology: The study of the body's natural defense mechanisms against disease.
Innovation: The process by which new products or new methods of production are introduced, including all the steps from the inventor's idea to bringing the new item to market.
Keyhole surgery: Also known as laparoscopic surgery. This is a surgical method of carrying out an operation without having to make a large incision. This type of surgery reduces the length of the hospital stay and leaves little scarring.
Kidney disease: Any one of several chronic conditions that are caused by damage to the cells of the kidney.
Laryngoscope: A medical instrument for examining the larynx.
Magnetic resonance imaging (MRI): A diagnostic procedure that uses a combination of large magnets, radiofrequencies, and a computer to produce detailed images of organs and structures within the body.
Material science: the scientific study of the chemical and physical properties of tangible substances out of which things are made.
Medical record: the case history of a medical patient.
Medical specialist: A physician who practices one branch of medicine.
Metabolic: Pertaining to the total of all the physical and chemical changes that take place in living organisms and cells.
Naturopathy: A method of treating disease using food and exercise and heat to assist the natural healing process.
Neurology: The special branch of medicine concerned with the nervous system and its disorders.
Nobel Prize: An annual award for outstanding contributions to chemistry or physics or physiology and medicine or literature or economics or peace.
Nuclear medicine: The branch of medicine that uses radioactive materials either to image a patient's body or to destroy diseased cells.
Ophthalmology: The medical specialty relating to the treatment of diseases and disorders of the eye.
Ophthalmoscope: An instrument specially designed to allow visualization of the back of the eye and lens.
Pacemaker: A surgically implanted electrical device used to cause heart contractions and control heartbeats.
Parkinson's disease: A degenerative disorder of the central nervous system characterized by tremor and impaired muscular coordination.
Pediatrics: The medical specialty concerned with the development, care and treatment of children from birth through adolescence.
Pharmacology: The science of the properties of drugs and their affects on the body.
Physics: The science that deals with matter and energy and their interactions in the fields that would include, optics, heat, electricity, magnetism, atomic structure, and others.
Pleurisy: An inflammation of the inner lining of the chest wall often resulting in chest pain worse on coughing and deep breathing.
Pneumonia: An inflammation of the lungs attended with chill, sudden temperature elevation, rapid breathing, pain in the side, and cough.
Polio: A viral infection that attacks the motor neurons in the brainstem and spinal cord and may produce paralysis.
Positron Emission Tomography (PET): A nuclear medicine diagnostic imaging technology for observing the functions of organs and tissue by mapping the emission of particles called positrons from decay of radioactive elements injected into the body.

Prosthetics: The branch of medicine dealing with the production and use of artificial body parts.
Psychiatric/psychological therapies: The field of medicine that diagnoses and treats psychological disorders by using medical or psychological forms of therapy.
Radial keratotomy: A surgical technique employing radial incision made in the periphery of the eye cornea to reduce nearsightedness.
Radiology: The branch of medicine that is concerned with the use of various forms of radiation for diagnostic and therapeutic uses.
Radiopaque dye: A dye, such as Barium sulfate, that is impenetrable to X-rays and appears as a light area on a radiograph.
Rapid prototyping: The conversion of an electronic computer-aided design model into a solid physical model directly from its digital representation.
Reconstructive: Methods and procedures that help restore to good condition; "reconstructive surgery"; "rehabilitative exercises."
Respirator: A mechanical device used to substitute for, or to assist with, breathing.
Resuscitation: The act of reviving a person and returning them to consciousness.
Robotics: The use of automated machines to replace human effort or the technology of building machines (robots) with computer intelligence and humanlike physical capabilities.
Sensor: A device that responds to a physical stimulus, such as thermal energy, electromagnetic energy, acoustic energy, pressure, magnetism, or motion, by producing a signal, usually electrical.
Serendipity: The phenomenon of making discoveries by accident. In science, serendipity is the discovery though methods that run counter to established research experiments, such as the discovery of penicillin. The coinage of the term is attributed to the British writer Horace Walpole from a Persian tale "The Three Princes of Serendip" where the heroes make discoveries accidentally.
Microscope: An instrument that magnifies objects by means of lenses so as to reveal details invisible to the naked eye.
Sociology: The science that deals with the organization of social groups and how they change or stay the same.
Specimen: A piece or portion of a sample or other material taken to be tested. Specimens normally are prepared to conform to an applicable test method. In medical technology, a fluid, excrement, or tissue sample.
Sphygmomanometer: An instrument used to measure blood pressure.
Stethoscope: an instrument used to listen to the heart and other sounds in the body.
Suture: The closing of a cut or wound by the use of stitches.
Syphilis: A venereal disease that can cause lesions of the central nervous system and the cardiovascular system.
Telemedicine: The use of medical information exchanged from one site to another using electronic communications for the health and education of patients or providers and to improve patient care.
Therapeutics: The general name applied to different methods of treatment and healing.
Thermodynamics: A branch of physics that explains the effect of temperature and heat, and the conversion of energy from one form to another.
Thermometer: A device for measuring temperature.
Tomography: A technique used in remote sensing for retrieving atmospheric parameters in a plane (cross-section) by taking measurements at different angles (and possibly different frequencies).
Tonsillectomy: Surgical removal of the tonsils, usually to treat tonsillitis.
Tuberculosis: A disease, also know as consumption or "TB," which causes small rounded swellings (tubercles) to form on mucous membranes; pulmonary tuberculosis affects the lungs.
Ultrasound: A diagnostic imaging technique which uses high-frequency sound waves and a computer to create images of blood vessels, tissues, and organs. This imaging technique is typically used to take pictures of an unborn fetus.
Urinalysis: The chemical analysis of urine.
Veterinary medicine: The branch of medicine that deals with the diagnosis and treatment of diseases and injuries of animals (especially domestic animals).
World view: The beliefs about the limits and workings of the world shared by the members of a society and represented in their myths, lore, ceremonies, social conduct, and general values.
X-ray: A diagnostic test which uses invisible electromagnetic energy beams to produce images of internal tissues, bones, and organs onto film.

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