Dee McGonigle
Kathleen Garver Mastrian

FOURTH EDITION

NURSING INFORMATICS

and the Foundation of Knowledge

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The Pedagogy

Nursing Informatics and the Foundation of Knowledge, Fourth Edition drives comprehension through a variety of strategies geared toward meeting the learning needs of students, while also generating enthusiasm about the topic. This interactive approach addresses diverse learning styles, making this the ideal text to ensure mastery of key concepts. The pedagogical aids that appear in most chapters include the following:

Key Terms

- Artificial intelligence
- Brain
- Cognitive informatics
- Cognitive science
- Computer science
- Connectionism
- Decision making
- Empiricism
- Epistemology
- Human Mental Workload (MWL)
- Intelligence
- Intuition
- Knowledge
- Logic
- Memory
- Mind
- Neuroscience
- Perception

Key Terms Found in a list at the beginning of each chapter, studying these terms will create an expanded vocabulary.

Objectives Providing a snapshot of the key information encountered in each chapter, the objectives serve as a checklist to help guide and focus study. Objectives can also be found within the text's online resources.

Objectives

1. Trace the evolution of nursing informatics from concept to specialty practice.
2. Relate nursing informatics metastructures, concepts, and tools to the knowledge work of nursing.
3. Explore the quest for consistent terminology in nursing and describe terminology approaches that

Introduction

Those who followed the actual events of Apollo 13, or who were entertained by the movie (Howard, 1995), watched the astronauts strive against all odds to bring their crippled spaceship back to Earth. The speed of their travel was incomprehensible to most viewers, and the task of bringing the spaceship back to Earth seemed nearly impossible. They were experiencing a crisis never imagined by the experts at NASA, and they made up their survival plan moment by moment. What brought them back to Earth safely? Surely, credit must be given to the technology and the spaceship's ability to withstand the trauma it experienced. Most amazing, however, were the traditional nontechnological tools, skills, and supplies that were used in new and different ways to stabilize the spacecraft's environment and keep the astronauts safe while traveling toward their uncertain future.

This sense of constancy in the midst of change serves to stabilize experience in many different life events and contributes to the survival of crisis and change. This rhythmic process is also vital to the healthcare system's stability and survival in the presence of the rapidly changing events of the Knowledge Age. No one can dispute the fact that the Knowledge Age is changing health care in ways that will not be fully recognized and understood for years. The change is paradigmatic, and every expert who addresses this change reminds healthcare professionals of the need to go with the flow of rapid change or be left behind.

As with any paradigm shift, a new way of viewing the world brings with it some of the enduring values of the previous worldview. As health care continues its journey into digital communications, telehealth, and wearable technologies, it brings some familiar tools and skills recognized in the form of **values**, such as **privacy**, **confidentiality**, autonomy, and nonmaleficence. Although these basic values remain unchanged, the **standards** for living out these values will take on new meaning as health professionals confront new and different moral dilemmas brought on by the adoption

Introductions Found at the beginning of each chapter, the introductions provide an overview highlighting the importance of the chapter's topic. They also help keep students focused as they read.

Research Briefs These summaries encourage students to access current research in the field.

RESEARCH BRIEF

Using an online survey of 1,227 randomly selected respondents, Bodkin and Miaoulis (2007) sought to describe the characteristics of information seekers on e-health websites, the types of information they seek, and their perceptions of the quality and ethics of the websites. Of the respondents, 74% had sought health information on the Web, with women accounting for 55.8% of the health information seekers. A total of 50% of the seekers were between 35 and 54 years of age. Nearly two thirds of the users began their searches using a general search engine rather than a health-specific site, unless they were seeking information related to symptoms or diseases. Top reasons for seeking information were related to diseases or symptoms of medical conditions, medication information, health news, health insurance, locating a doctor, and Medicare or Medicaid information. The level of education of information seekers was related to the ratings of website quality, in that more educated seekers found health information websites more understandable, but were more likely to perceive bias in the website information. The researchers also found that the ethical codes for e-health websites seem to be increasing consumers' trust in the safety and quality of information found on the Web, but that most consumers are not comfortable purchasing health products or services online.

The full article appears in Bodkin, C., & Miaoulis, G. (2007). eHealth information quality and ethics issues: An exploratory study of consumer perceptions. *International Journal of Pharmaceutical and Healthcare Marketing, 1*(1), 27–42. Retrieved from ABI/INFORM Global (Document ID: 1515583081).

Summaries Summaries are included at the end of each chapter to provide a concise review of the material covered, highlighting the most important points and describing what the future holds.

Summary

In this chapter, we have traced the development of informatics as a specialty, defined nursing informatics, and explored the DIKW paradigm central to informatics. We also explored the need for and the development of standardized terminologies to capture and codify the work of nursing and how informatics supports the knowledge work of nursing. This chapter advanced the view that every nurse's practice will make contributions to new nursing knowledge in dynamically interactive CIS environments. The core concepts associated with informatics will become embedded in the practice of every nurse, whether administrator, researcher, educator, or practitioner. Informatics will be prominent in the knowledge work of nurses, yet it will be a subtlety because of its eventual fulsome integration with clinical care processes. Clinical care will be substantially supported by the capacity and promise of technology today and tomorrow.

Most importantly, readers need to contemplate a future without being limited by the world of practice as it is known today. Information technology is not a panacea for all of the challenges found in health care, but it will provide the nursing profession with an unprecedented capacity to generate and disseminate new knowledge at rapid speed. Realizing these possibilities necessitates that all nurses understand and leverage the informatician within and contribute to the future.

BOX 6-3 CASE STUDY: CASTING TO THE FUTURE

In the year 2025, nursing practice enabled by technology has created a professional culture of reflection, critical inquiry, and interprofessional collaboration. Nurses use technology at the point of care in all clinical settings (e.g., primary care, acute care, community, and long-term care) to inform their clinical decisions and effect the best possible outcomes for their clients. Information is gathered and retrieved via human–technology biometric interfaces including voice, visual, sensory, gustatory, and auditory interfaces, which continuously monitor physiologic parameters for potentially harmful imbalances. Longitudinal records are maintained for all citizens from their initial prenatal assessment to death; all lifelong records are aggregated into the knowledge bases of expert systems. These systems provide the basis of the artificial intelligence being embedded in emerging technologies. Smart technologies and invisible computing are ubiquitous in all sectors where care is delivered. Clients and families are empowered to review and contribute actively to their record of health and wellness. Invasive diagnostic techniques are obsolete, nanotechnology therapeutics are the norm, and robotics supplement or replace much of the traditional work of all health professions. Nurses provide expertise to citizens to help them effectively manage their health and wellness life plans, and navigate access to appropriate information and services.

Case Studies Case studies encourage active learning and promote critical thinking skills. Students can ask questions, analyze situations, and solve problems in a real-world context.

THOUGHT-PROVOKING QUESTIONS

1. Imagine you are in a social situation and someone asks you, "What does a nurse do?" Think about how you will capture and convey the richness that is nursing science in your answer.
2. Choose a clinical scenario from your recent experience and analyze it using the Foundation of Knowledge model. How did you acquire knowledge? How did you process knowledge? How did you generate knowledge? How did you disseminate knowledge? How did you use feedback, and what was the effect of the feedback on the foundation of your knowledge?

Thought-Provoking Questions Students can work on these critical thinking assignments individually or in a group. In addition, students can delve deeper into concepts by completing these exercises online.

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Preface

The idea for this text originated with the development of nursing informatics (NI) classes, the publication of articles related to technology-based education, and the creation of the *Online Journal of Nursing Informatics (OJNI)*, which Dee McGonigle cofounded with Renee Eggers. Like most nurse informaticists, we fell into the specialty; our love affair with technology and gadgets and our willingness to be the first to try new things helped to hook us into the specialty of informatics. The rapid evolution of technology and its transformation of the ways of nursing prompted us to try to capture the essence of NI in a text.

As we were developing the first edition, we realized that we could not possibly know all there is to know about informatics and the way in which it supports nursing practice, education, administration, and research. We also knew that our faculty roles constrained our opportunities for exposure to changes in this rapidly evolving field. Therefore, we developed a tentative outline and a working model of the theoretical framework for the text and invited participation from informatics experts and specialists around the world. We were pleased with the enthusiastic responses we received from some of those invited contributors and a few volunteers who heard about the text and asked to participate in their particular area of expertise.

In the second edition, we invited the original contributors to revise and update their chapters. Not everyone chose to participate in the second edition, so we revised several of the chapters using the original work as a springboard. The revisions to the text were guided by the contributors' growing informatics expertise and the reviews provided by textbook adopters. In the revisions, we sought to do the following:

- Expand the audience focus to include nursing students from BS through DNP programs as well as nurses thrust into informatics roles in clinical agencies.
- Include, whenever possible, an attention-grabbing case scenario as an introduction or an illustrative case scenario demonstrating why the topic is important.
- Include important research findings related to the topic. Many chapters have research briefs presented in text boxes to encourage the reader to access current research.
- Focus on cutting-edge innovations, meaningful use, and patient safety as appropriate to each topic.
- Include a paragraph describing what the future holds for each topic.

New chapters that were added to the second edition included those focusing on technology and patient safety, system development life cycle, workflow analysis, gaming, simulation, and bioinformatics.

In the third edition, we reviewed and updated all of the chapters, reordered some chapters for better content flow, eliminated duplicated content, split the education and research content into two sections, integrated social media content, and added two new chapters: *Data Mining as a Research Tool* and *The Art of Caring in Technology-Laden Environments*.

In this fourth edition, we reviewed and updated all of the chapters based on technological advancements and changes to the healthcare arena, including reimbursement mechanisms for services. We have pared this edition down to 26 chapters from the previous edition's 29; one chapter each was deleted from Sections II, V, and VII. Section I includes updates to the same five chapters on the building blocks of nursing informatics, with extensive changes to Chapter 3, *Computer Science and the Foundation of Knowledge Model*. To improve flow, we combined content. In Section II, the previous four chapters were narrowed to three. New Chapters 6, *History and Evolution of Nursing Informatics* and 7, *Nursing Informatics as* *a Specialty*, were developed and appropriate material from previous Chapters 6, 7, and 8 were assimilated. This section ends with an updated Chapter 8, *Legislative Aspects of Nursing Informatics: HITECH and HIPAA* (formerly Chapter 9). Section III contains the same five chapters, although all were updated and Chapter 13, *Workflow and Beyond Meaningful Use* (formerly Chapter 14) now reflects the payment models and reimbursement issues that we are adjusting to after meaningful use has gone away. Section IV contains the same five chapters with updated content and some name changes to reflect the current status of informatics and healthcare. Chapter 15 was renamed to *Informatics Tools to Promote Patient Safety and Quality Outcomes,* and Chapter 16 has been changed to *Patient Engagement and Connected Health*. Section V went from three chapters to two chapters: Chapter 19 (formerly Chapter 20) was updated, while the new Chapter 20, *Simulation, Game Mechanics, and Virtual Worlds in Nursing Education,* had content from former Chapters 21 and 22 integrated during its development. Section VI was renamed to Research Applications of Nursing Informatics. It still has the same four chapters, which have been updated, but the first chapter in this section, 21, was renamed to reflect nursing research; its new name is *Nursing Research: Data Collection, Processing, and Analysis*. Section VII went from three chapters to two chapters. Because emerging technologies are discussed throughout the text, the chapter focusing specifically on that was removed. The two chapters that remain are Chapter 25, *The Art of Caring in Technology-Laden Environments,* and the new Chapter 26, *Nursing Informatics and Knowledge Management*. In addition, the ancillary materials have been updated and enhanced to include competency-based self-assessments and mapping the content to the current NI standards.

We believe that this text provides a comprehensive elucidation of this exciting field. Its theoretical underpinning is the Foundation of Knowledge model. This model is introduced in its entirety in the first chapter (*Nursing Science and the Foundation of Knowledge*), which discusses nursing science and its relationship to NI. We believe that humans are organic information systems that are constantly acquiring, processing, and generating information or knowledge in both their professional and personal lives. It is their high degree of knowledge that characterizes humans as extremely intelligent, organic machines. Individuals have the ability to manage knowledge—an ability that is learned and honed from birth. We make our way through life interacting with our environment and being inundated with information and knowledge. We experience our environment and learn by acquiring, processing, generating, and disseminating knowledge. As we interact in our environment, we acquire knowledge that we must process. This processing effort causes us to redefine and restructure our knowledge base and generate new knowledge. We then share (disseminate) this new knowledge and receive feedback from others. The dissemination and feedback initiate this cycle of knowledge over again, as we acquire, process, generate, and disseminate the knowledge gained from sharing and re-exploring our own knowledge base. As others respond to our knowledge dissemination and we acquire new knowledge, we engage in rethinking and reflecting on our knowledge, processing, generating, and then disseminating anew.

The purpose of this text is to provide a set of practical and powerful tools to ensure that the reader gains an understanding of NI and moves from information through knowledge to wisdom. Defining the demands of nurses and providing tools to help them survive and succeed in the Knowledge Era remains a major challenge. Exposing nursing students and nurses to the principles and tools used in NI helps to prepare them to meet the challenge of practicing nursing in the Knowledge Era while striving to improve patient care at all levels.

The text provides a comprehensive framework that embraces knowledge so that readers can develop their knowledge repositories and the wisdom necessary to act on and apply that knowledge. The text is divided into seven sections.

- Section I, *Building Blocks of Nursing Informatics,* covers the building blocks of NI: nursing science, information science, computer science, cognitive science, and the ethical management of information.
- Section II, *Perspectives on Nursing Informatics,* provides readers with a look at various viewpoints on NI and NI practice as described by experts in the field.

- Section III, *Nursing Informatics Administrative Applications: Precare and Care Support,* covers important functions of administrative applications of NI.
- Section IV, *Nursing Informatics Practice Applications: Care Delivery,* covers healthcare delivery applications including electronic health records (EHRs), clinical information systems, telehealth, patient safety, patient and community education, and care management.
- Section V, *Education Applications of Nursing Informatics,* presents subject matter on how informatics supports nursing education.
- Section VI, *Research Applications of Nursing Informatics,* covers informatics tools to support nursing research, including data mining and bioinformatics.
- Section VII, *Imagining the Future of Nursing Informatics,* focuses on the future of NI, emphasizes the need to preserve caring functions in technology-laden environments, and reviews the relationship of nursing informatics to organizational knowledge management.

The introduction to each section explains the relationship between the content of that section and the Foundation of Knowledge model. This text places the material within the context of knowledge acquisition, processing, generation, and dissemination. It serves both nursing students (BS to DNP/PhD) and professionals who need to understand, use, and evaluate NI knowledge. As nursing professors, our major responsibility is to prepare the practitioners and leaders in the field. Because NI permeates the entire scope of nursing (practice, administration, education, and research), nursing education curricula must include NI. Our primary objective is to develop the most comprehensive and user-friendly NI text on the market to prepare nurses for current and future practice challenges. In particular, this text provides a solid groundwork from which to integrate NI into practice, education, administration, and research.

Goals of this text are as follows:

- Impart core NI principles that should be familiar to every nurse and nursing student
- Help the reader understand knowledge and how it is acquired, processed, generated, and disseminated
- Explore the changing role of NI professionals
- Demonstrate the value of the NI discipline as an attractive field of specialization

Meeting these goals will help nurses and nursing students understand and use fundamental NI principles so that they efficiently and effectively function as current and future nursing professionals to enhance the nursing profession and improve the quality of health care. The overall vision, framework, and pedagogy of this text offer benefits to readers by highlighting established principles while drawing out new ones that continue to emerge as nursing and technology evolve.

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Authors' Note

This text provides an overview of nursing informatics from the perspective of diverse experts in the field, with a focus on nursing informatics and the Foundation of Knowledge model. We want our readers and students to focus on the relationship of knowledge to informatics and to embrace and maintain the caring functions of nursing—messages all too often lost in the romance with technology. We hope you enjoy the text!

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SECTION I

Building Blocks of Nursing Informatics

Chapter 1 Nursing Science and the Foundation of Knowledge

Chapter 2 Introduction to Information, Information Science, and Information Systems

Chapter 3 Computer Science and the Foundation of Knowledge Model

Chapter 4 Introduction to Cognitive Science and Cognitive Informatics

Chapter 5 Ethical Applications of Informatics

Nursing professionals are information-dependent knowledge workers. As health care continues to evolve in an increasingly competitive information marketplace, professionals—that is, the knowledge workers—must be well prepared to make significant contributions by harnessing appropriate and timely information. Nursing informatics (NI), a product of the scientific synthesis of information in nursing, encompasses concepts from computer science, cognitive science, information science, and nursing science. NI continues to evolve as more and more professionals access, use, and develop the information, computer, and cognitive sciences necessary to advance nursing science for the betterment of patients and the profession. Regardless of their future roles in the healthcare milieu, it is clear that nurses need to understand the ethical application of computer, information, and cognitive sciences to advance nursing science.

To implement NI, one must view it from the perspective of both the current healthcare delivery system and specific, individual organizational needs, while anticipating and creating future applications in both the healthcare system and the nursing profession. Nursing professionals should be expected to discover opportunities to use NI, participate in the design of solutions, and be challenged to identify, develop, evaluate, modify, and enhance applications to improve patient care. This text is designed to provide the reader with the information and knowledge needed to meet this expectation.

Section I presents an overview of the building blocks of NI: nursing, information, computer, and cognitive sciences. Also included in this section is a chapter on ethical applications of healthcare informatics. This section lays the foundation for the remainder of the book.

The *Nursing Science and the Foundation of Knowledge* chapter describes nursing science and introduces the Foundation of Knowledge model as the conceptual framework for the book. In this chapter, a clinical case scenario is used to illustrate the concepts central to nursing science. A definition of nursing science is also derived from the American Nurses Association's definition of nursing. Nursing science is the ethical application of knowledge acquired through education, research, and practice to provide services and interventions to patients to maintain, enhance, or restore their health, and to acquire, process, generate, and disseminate nursing knowledge to advance the nursing profession. Information is a central concept and health care's most valuable resource. Information science and systems, together with computers, are constantly changing the way healthcare organizations conduct their business. This will continue to evolve.

To prepare for these innovations, the reader must understand fundamental information and computer concepts, covered in the *Introduction to Information, Information Science, and Information Systems* and *Computer Science and the Foundation of Knowledge Model* chapters, respectively. Information science deals with the interchange (or flow) and scaffolding (or structure) of information and involves the application of information tools for solutions to patient care and business problems in health care. To be able to use and synthesize information effectively, an individual must be able to obtain, perceive, process, synthesize, comprehend, convey, and manage the information. Computer science deals with understanding the development, design, structure, and relationship of computer hardware and software. This science offers extremely valuable tools that, if used skillfully, can facilitate the acquisition and manipulation of data and information by nurses, who can then synthesize these resources into an ever-evolving knowledge and wisdom base. This not only facilitates professional development and the ability to apply evidence-based practice decisions within nursing care, but, if the results are disseminated and shared, can also advance the profession's knowledge base. The development of knowledge tools, such as the automation of decision making and strides in artificial intelligence, has altered the understanding of knowledge and its representation. The ability to structure knowledge electronically facilitates the ability to share knowledge structures and enhance collective knowledge.

As discussed in the *Introduction to Cognitive Science and Cognitive Informatics* chapter, cognitive science deals with how the human mind functions. This science encompasses how people think, understand, remember, synthesize, and access stored information and knowledge. The nature of knowledge, including how it is developed, used, modified, and shared, provides the basis for continued learning and intellectual growth.

The *Ethical Applications of Informatics* chapter focuses on ethical issues associated with managing private information with technology and provides a framework for analyzing ethical issues and supporting ethical decision making.

The material within this book is placed within the context of the Foundation of Knowledge model (shown in **Figure I-1** and periodically throughout the book, but more fully introduced and explained in the *Nursing Science and the Foundation of Knowledge* chapter). The Foundation of Knowledge model is used throughout the text to illustrate how knowledge is used to meet the needs of healthcare delivery systems, organizations, patients, and nurses. It is through interaction with these building blocks—the theories, architecture, and tools—that one acquires the bits and pieces of data necessary, processes these into information, and generates and disseminates the resulting knowledge. Through this dynamic exchange, which includes feedback, individuals continue the interaction and use of these sciences to input or acquire, process, and output or disseminate generated knowledge. Humans experience their environment and learn by acquiring, processing, generating, and disseminating knowledge. When they then share (disseminate) this new knowledge and receive feedback on the knowledge they have shared, the feedback initiates the cycle of knowledge all over again. As individuals acquire, process, generate, and disseminate knowledge, they are motivated to share, rethink, and explore their own knowledge base. This complex process is captured in the Foundation of Knowledge model. Throughout the chapters in the *Building Blocks of Nursing Informatics* section, readers are challenged to think about how the model can help them to understand the ways in which they acquire, process, generate, disseminate, and then receive and process feedback on their new knowledge of the building blocks of NI.

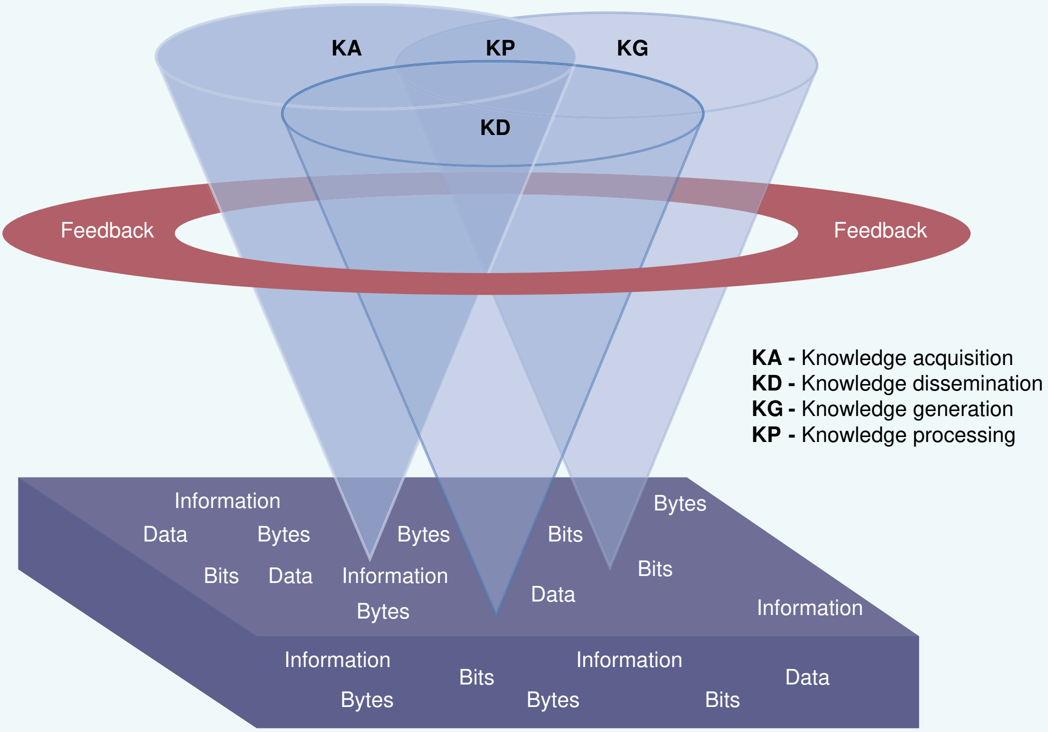

Figure I-1 Foundation of Knowledge Model
Designed by Alicia Mastrian

Objectives

1. Define nursing science and its relationship to various nursing roles and nursing informatics.
2. Introduce the Foundation of Knowledge model as the organizing conceptual framework for the text.
3. Explain the relationships among knowledge acquisition, knowledge processing, knowledge generation, knowledge dissemination, and wisdom.

Key Terms

- Borrowed theory
- Building blocks
- Clinical databases
- Clinical practice guidelines
- Conceptual framework
- Data
- Data mining
- Evidence
- Feedback
- Foundation of Knowledge model
- Information
- Knowledge
- Knowledge acquisition
- Knowledge dissemination
- Knowledge generation
- Knowledge processing
- Knowledge worker
- Nursing informatics
- Nursing science
- Nursing theory
- Relational database
- Transparent wisdom

CHAPTER 1

Nursing Science and the Foundation of Knowledge

Dee McGonigle and Kathleen Mastrian

Introduction

Nursing informatics has been traditionally defined as a specialty that integrates **nursing science**, computer science, and information science to manage and communicate data, information, knowledge, and wisdom in nursing practice. This chapter focuses on nursing science as one of the **building blocks** of nursing informatics. As depicted in **Figure 1-1**, the traditional definition of nursing

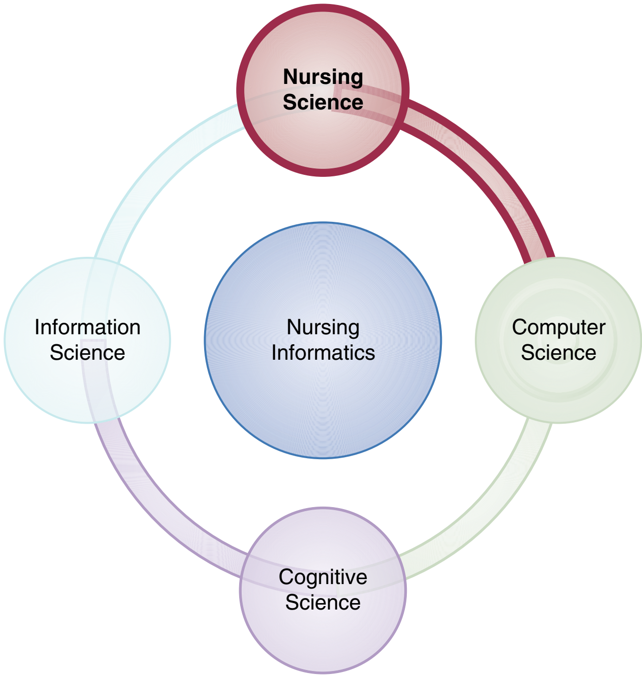

Figure 1-1 Building Blocks of Nursing Informatics

informatics is extended to include cognitive science. The **Foundation of Knowledge model** is also introduced as the organizing **conceptual framework** of this text, and the model is tied to nursing science and the practice of nursing informatics. To lay the groundwork for this discussion, consider the following patient scenario:

> *Tom H. is a registered nurse who works in a very busy metropolitan hospital emergency room. He has just admitted a 79-year-old man whose wife brought him to the hospital because he is having trouble breathing. Tom immediately clips a pulse oximeter to the patient's finger and performs a very quick assessment of the patient's other vital signs. He discovers a rapid pulse rate and a decreased oxygen saturation level in addition to the rapid and labored breathing. Tom determines that the patient is not in immediate danger and that he does not require intubation. Tom focuses his initial attention on easing the patient's labored breathing by elevating the head of the bed and initiating oxygen treatment; he then hooks the patient up to a heart monitor. Tom continues to assess the patient's breathing status as he performs a head-to-toe assessment of the patient that leads to the nursing diagnoses and additional interventions necessary to provide comprehensive care to this patient.*

Consider Tom's actions and how and why he intervened as he did. Tom relied on the immediate **data** and **information** that he acquired during his initial rapid assessment to deliver appropriate care to his patient. Tom also used technology (a pulse oximeter and a heart monitor) to assist with and support the delivery of care. What is not immediately apparent, and some would argue is transparent (done without conscious thought), is the fact that during the rapid assessment, Tom reached into his **knowledge** base of previous learning and experiences to direct his care, so that he could act with **transparent wisdom**. He used both **nursing theory** and **borrowed theory** to inform his practice. Tom certainly used nursing process theory, and he may have also used one of several other nursing theories, such as Rogers's science of unitary human beings, Orem's theory of self-care deficit, or Roy's adaptation theory. In addition, Tom may have applied his knowledge from some of the basic sciences, such as anatomy, physiology, psychology, and chemistry, as he determined the patient's immediate needs. Information from Maslow's hierarchy of needs, Lazarus's transaction model of stress and coping, and the health belief model may have also helped Tom practice professional nursing. He gathered data, and then analyzed and interpreted those data to form a conclusion—the essence of science. Tom has illustrated the practical aspects of nursing science.

The American Nurses Association (2016) defines nursing in this way: "Nursing is the protection, promotion, and optimization of health and abilities, prevention of illness and injury, facilitation of healing, alleviation of suffering through the diagnosis and treatment of human response, and advocacy in the care of individuals, families, groups, communities, and populations" (para. 1). Thus the focus of nursing is on human responses to actual or potential health problems and advocacy for various clients. These human responses are varied and may change over time in a single case. Nurses must possess the technical skills to manage equipment and perform procedures, the interpersonal skills to interact appropriately with people, and the cognitive skills to observe, recognize, and collect data; analyze and interpret data; and reach a reasonable conclusion that forms the basis of a decision. At the heart of all of these skills lies the management of data and information. This definition of nursing science focuses on the ethical application of knowledge acquired through education, research, and practice to provide services and interventions to patients to maintain, enhance, or restore their health and to acquire, process, generate, and disseminate nursing knowledge to advance the nursing profession.

Nursing is an information-intensive profession. The steps of using information, applying knowledge to a problem, and acting with wisdom form the basis of nursing practice science. Information is composed of data that were processed using knowledge. For information to be valuable, it must be accessible, accurate, timely, complete, cost-effective, flexible, reliable, relevant, simple, verifiable, and secure. Knowledge is the awareness and understanding of a set of information and ways that information can be made useful to support a specific task or arrive at a decision. In the case scenario, Tom used accessible, accurate, timely, relevant, and verifiable data and information. He compared that data and information to his knowledge base of previous experiences to determine which data and information were relevant to the current case. By applying his previous knowledge to data, he converted those data into information, and information into new knowledge—that is, an understanding of which nursing interventions were appropriate in this case. Thus information is data made functional through the application of knowledge.

Humans acquire data and information in bits and pieces and then transform the information into knowledge. The information-processing functions of the brain are frequently compared to those of a computer, and vice versa (see a discussion of cognitive informatics for more information). Humans can be thought of as organic information systems that are constantly acquiring, processing, and generating information or knowledge in their professional and personal lives. They have an amazing ability to manage knowledge. This ability is learned and honed from birth as individuals make their way through life interacting with the environment and being inundated with data and information. Each person experiences the environment and learns by acquiring, processing, generating, and disseminating knowledge.

Tom, for example, acquired knowledge in his basic nursing education program and continues to build his foundation of knowledge by engaging in such activities as reading nursing research and theory articles, attending continuing education programs, consulting with expert colleagues, and using **clinical databases** and **clinical practice guidelines**. As he interacts in the environment, he acquires knowledge that must be processed. This processing effort causes him to redefine and restructure his knowledge base and generate new knowledge. Tom can then share (disseminate) this new knowledge with colleagues, and he may receive **feedback** on the knowledge that he shares. This dissemination and feedback builds the knowledge foundation anew as Tom acquires, processes, generates, and disseminates new knowledge as a result of his interactions. As others respond to his **knowledge dissemination** and he acquires yet more knowledge, he is engaged to rethink, reflect on, and re-explore his **knowledge acquisition**, leading to further processing, generating, and then disseminating knowledge. This ongoing process is captured in the Foundation of Knowledge model, which is used as an organizing framework for this text.

At its base, the model contains bits, bytes (a computer term used to quantify data), data, and information in a random representation. Growing out of the base are separate cones of light that expand as they reflect upward; these cones represent knowledge acquisition, **knowledge generation**, and knowledge dissemination. At the intersection of the cones and forming a new cone is **knowledge processing**. Encircling and cutting through the knowledge cones is feedback that acts on and may transform any or all aspects of knowledge represented by the cones. One should imagine the model as a dynamic figure in which the cones of light and the feedback rotate and interact rather than remain static. Knowledge acquisition, knowledge generation, knowledge dissemination, knowledge processing, and feedback are constantly evolving for nurse scientists. The transparent effect of the cones is deliberate and is intended to suggest that as knowledge grows and expands, its use becomes more transparent—a person uses this knowledge during practice without even being consciously aware of which aspect of knowledge is being used at any given moment.

Experienced nurses, thinking back to their novice years, may recall feeling like their head was filled with bits of data and information that did not form any type of cohesive whole. As the model depicts, the processing of knowledge begins a bit later (imagine a timeline applied vertically) with early experiences on the bottom and expertise growing as the processing of knowledge ensues. Early on in nurses' education, conscious attention is focused mainly on knowledge acquisition, and beginning nurses depend on their instructors and others to process, generate, and disseminate knowledge. As nurses become more comfortable with the science of nursing, they begin to take over some of the other Foundation of Knowledge functions. However, to keep up with the explosion of information in nursing and health care, they must continue to rely on the knowledge generation of nursing theorists and researchers and the dissemination of their work. In this sense, nurses are committed to lifelong learning and the use of knowledge in the practice of nursing science.

The Foundation of Knowledge model (**Figure 1-2**) permeates this text, reflecting the understanding that knowledge is a powerful tool and that nurses focus on information as a key building block of knowledge. The application of the model is described to help the reader understand and appreciate the foundation of knowledge in nursing science and see how it applies to nursing informatics. All of the various nursing roles (practice, administration, education, research, and informatics) involve the science of nursing. Nurses are **knowledge workers**, working with information and generating information and knowledge as a product. They are knowledge acquirers, providing convenient and efficient means of capturing and storing knowledge. They are knowledge users, meaning individuals or groups who benefit from valuable, viable knowledge. Nurses are knowledge engineers, designing, developing, implementing, and maintaining knowledge. They are knowledge managers, capturing and processing collective expertise and distributing it where it can create the largest benefit. Finally,

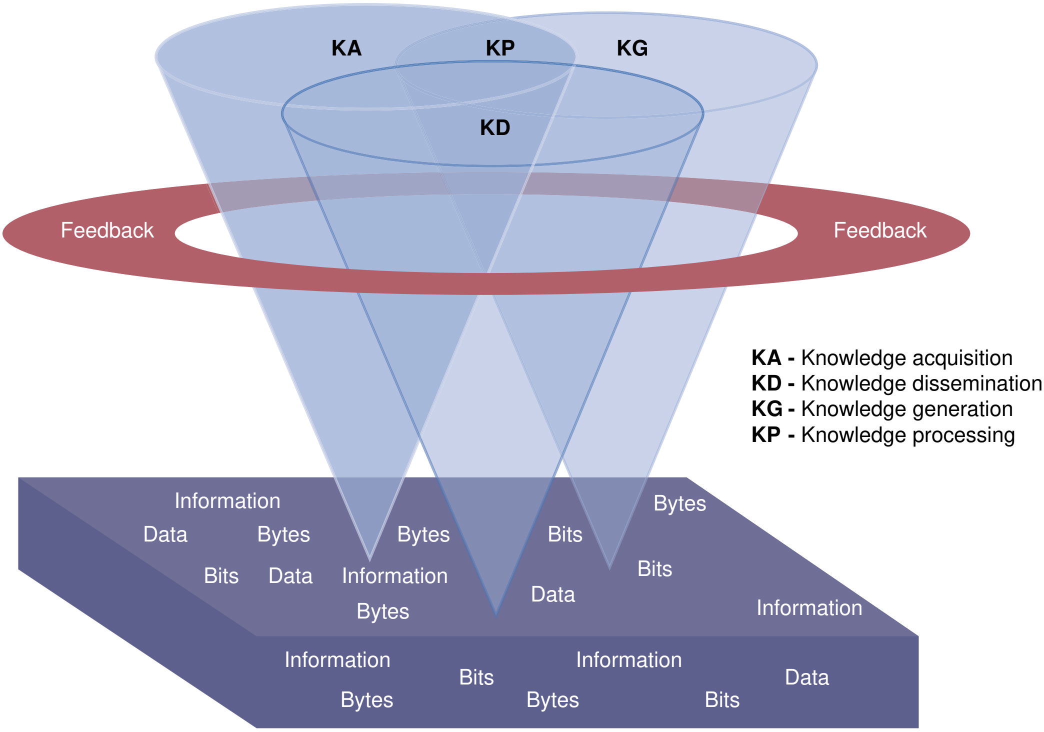

Figure 1-2 Foundation of Knowledge Model
Designed by Alicia Mastrian

they are knowledge developers and generators, changing and evolving knowledge based on the tasks at hand and the information available.

In the case scenario, at first glance one might label Tom as a knowledge worker, a knowledge acquirer, and a knowledge user. However, stopping here might sell Tom short in his practice of nursing science. Although he acquired and used knowledge to help him achieve his work, he also processed the data and information he collected to develop a nursing diagnosis and a plan of care. The knowledge stores Tom used to develop and glean knowledge from valuable information are generative (having the ability to originate and produce or generate) in nature. For example, Tom may have learned something new about his patient's culture from the patient or his wife that he will file away in the knowledge repository of his mind to be used in another similar situation. As he compares this new cultural information to what he already knows, he may gain insight into the effect of culture on a patient's response to illness. In this sense, Tom is a knowledge generator. If he shares this newly acquired knowledge with another practitioner, and as he records his observations and his conclusions, he is then disseminating knowledge. Tom also uses feedback from the various technologies he has applied to monitor his patient's status. In addition, he may rely on feedback from laboratory reports or even other practitioners to help him rethink, revise, and apply the knowledge about this patient that he is generating.

To have ongoing value, knowledge must be viable. Knowledge viability refers to applications (most technology based) that offer easily accessible, accurate, and timely information obtained from a variety of resources and methods and presented in a manner so as to provide the necessary elements to generate new knowledge. In the case scenario, Tom may have felt the need to consult an electronic database or a clinical guidelines repository that he has downloaded on his tablet or smartphone, or that resides in the emergency room's networked computer system, to assist him in the development of a comprehensive care plan for his patient. In this way, Tom uses technology and **evidence** to support and inform his practice. It is also possible in this scenario that an alert might appear in the patient's electronic health record or the clinical information system (CIS) reminding Tom to ask about influenza and pneumonia vaccines. Clinical information technologies that support and inform nursing practice and nursing administration are an important part of nursing informatics.

This text provides a framework that embraces knowledge so that readers can develop the wisdom necessary to apply what they have learned. Wisdom is the application of knowledge to an appropriate situation. In the practice of nursing science, one expects actions to be directed by wisdom. Wisdom uses knowledge and experience to heighten common sense and insight to exercise sound judgment in practical matters. It is developed through knowledge, experience, insight, and reflection. Wisdom is sometimes thought of as the highest form of common sense, resulting from accumulated knowledge or erudition (deep, thorough learning) or enlightenment (education that results in understanding and the dissemination of knowledge). It is the ability to apply valuable and viable knowledge, experience, understanding, and insight while being prudent and sensible. Knowledge and wisdom are not synonymous: Knowledge abounds with others' thoughts and information, whereas wisdom is focused on one's own mind and the synthesis of experience, insight, understanding, and knowledge. Wisdom has been called the foundation of the art of nursing.

Some nursing roles might be viewed as more focused on some aspects rather than other aspects of the foundation of knowledge. For example, some might argue that nurse educators are primarily knowledge disseminators and that nurse researchers are knowledge generators. Although the more frequent output of their efforts can certainly be viewed in this way, it is important to realize that nurses use all of the aspects of the Foundation of Knowledge model regardless of their area of practice. For nurse educators to be effective, they must be in the habit of constantly building and rebuilding their foundation of knowledge about nursing science. In addition, as they develop and implement curricular innovations, they must evaluate the effectiveness of those changes. In some cases, they use formal research techniques to achieve this goal and, therefore, generate knowledge about the best and most effective teaching strategies. Similarly, nurse researchers must acquire and process new knowledge as they design and conduct their research studies. All nurses have the opportunity to be involved in the formal dissemination of knowledge via their participation in professional conferences, either as presenters or as attendees. In addition, some nurses disseminate knowledge by formal publication of their ideas. In the cases of conference presentation and publication, nurses may receive feedback that stimulates rethinking about the knowledge they have generated and disseminated, in turn prompting them to acquire and process data and information anew.

All nurses, regardless of their practice arena, must use informatics and technology to inform and support that practice. The case scenario discussed Tom's use of various monitoring devices that provide feedback on the physiologic status of the patient. It was also suggested that Tom might consult a clinical database or nursing practice guidelines residing on a tablet or smartphone, in the cloud (a virtual information storage system), or on a clinical agency network as he develops an appropriate plan of action for his nursing interventions. Perhaps the CIS in the agency supports the collection of data about patients in a **relational database**, providing an opportunity for **data mining** by nursing administrators or nurse researchers. In this way, administrators and researchers can glean information about best practices and determine which improvements are necessary to deliver the best and most effective nursing care (Swan, Lang, & McGinley, 2004).

The future of nursing science and nursing informatics is closely associated with nursing education and nursing research. Skiba (2007) suggested that techno-savvy and well-informed faculty who can demonstrate the appropriate use of technologies to enhance the delivery of nursing care are needed. Along those lines, Whitman-Price, Kennedy, and Godwin (2012) conducted research among senior nursing students to determine perceptions of personal phone use to access healthcare information during clinical. Their study indicated that ready access to electronic resources enhanced clinical decision making and confidence in patient care. Girard (2007) discussed cutting-edge operating room technologies, such as nanosurgery using nanorobots, smart fabrics that aid in patient assessment during surgery, biopharmacy techniques for the safe and effective delivery of anesthesia, and virtual reality training. She made an extremely provocative point about nursing education: "Educators will need to expand their knowledge and teach for the future and not the past. They must take heed that the old tried-and-true nursing education methods and curriculum that has lasted 100 years will have to change, and that change will be mandated for all areas of nursing" (p. 353). Bassendowski (2007) specifically addressed the potential for the generation of knowledge in educational endeavors as faculty apply new technologies to teaching and the focus shifts away from individual to group instruction that promotes sharing and processing of knowledge.

Several key national groups continue to promote the inclusion of informatics content in nursing education programs. These initiatives include the Vision Series by the National League for Nursing (NLN; 2015); recommendations in the *Quality and Safety Education for Nurses (QSEN)* learning modules (2014a); the Technology Informatics Guiding Education Reform (TIGER) Initiative (Healthcare Information and Management Systems Society, 2016); and Nursing Informatics Deep Dive by the American Association of Colleges of Nursing (AACN; 2016). These organizations focus on the need to integrate informatics competencies into nursing curricula to prepare future nurses for the tasks of managing data, information, and knowledge; alleviating errors and promoting safety; supporting decision making; and improving the quality of patient care. Nurse educators are challenged to prepare informatics-competent nurses who can practice safely in technology-laden settings.

The TIGER (2007) initiative identified steps toward a 10-year vision and stated a key purpose: "to create a vision for the future of nursing that bridges the quality chasm with information technology, enabling nurses to use informatics in practice and education to provide safer, higher-quality patient care" (p. 4). The pillars of the TIGER vision include the following:

- *Management and Leadership*: Revolutionary leadership that drives, empowers, and executes the transformation of health care.
- *Education*: Collaborative learning communities that maximize the possibilities of technology toward knowledge development and dissemination, driving rapid deployment and implementation of best practices.
- *Communication and Collaboration*: Standardized, person-centered, technology-enabled processes to facilitate teamwork and relationships across the continuum of care.
- *Informatics Design*: Evidence-based, interoperable intelligence systems that support education and practice to foster quality care and safety.
- *Information Technology*: Smart, people-centered, affordable technologies that are universal, useable, useful, and standards based.
- *Policy*: Consistent, incentives-based initiatives (organizational and governmental) that support advocacy and coalition-building, achieving and resourcing an ethical culture of safety.
- *Culture*: A respectful, open system that leverages technology and informatics across multiple disciplines in an environment where all stakeholders trust each other to work together toward the goal of high quality and safety (p. 4).

The Essentials of Baccalaureate Education for Professional Nursing Practice (AACN, 2008, pp. 18–19) includes the following technology-related outcomes for baccalaureate nursing graduates:

1. Demonstrate skills in using patient care technologies, information systems, and communication devices that support safe nursing practice.
2. Use telecommunication technologies to assist in effective communication in a variety of healthcare settings.
3. Apply safeguards and decision-making support tools embedded in patient care technologies and information systems to support a safe practice environment for both patients and healthcare workers.
4. Understand the use of CIS to document interventions related to achieving nurse-sensitive outcomes.
5. Use standardized terminology in a care environment that reflects nursing's unique contribution to patient outcomes.
6. Evaluate data from all relevant sources, including technology, to inform the delivery of care.
7. Recognize the role of information technology in improving patient care outcomes and creating a safe care environment.
8. Uphold ethical standards related to data security, regulatory requirements, confidentiality, and clients' right to privacy.
9. Apply patient care technologies as appropriate to address the needs of a diverse patient population.
10. Advocate for the use of new patient care technologies for safe, quality care.

11. Recognize that redesign of workflow and care processes should precede implementation of care technology to facilitate nursing practice.
12. Participate in the evaluation of information systems in practice settings through policy and procedure development.

The report suggests the following sample content for achieving these student outcomes (AACN, 2008, pp. 19–20):

- Use of patient care technologies (e.g., monitors, pumps, computer-assisted devices)
- Use of technology and information systems for clinical decision making
- Computer skills that may include basic software, spreadsheet, and healthcare databases
- Information management for patient safety
- Regulatory requirements through electronic data-monitoring systems
- Ethical and legal issues related to the use of information technology, including copyright, privacy, and confidentiality issues
- Retrieval information systems, including access, evaluation of data, and application of relevant data to patient care
- Online literature searches
- Technological resources for evidence-based practice
- Web-based learning and online literature searches for self and patient use
- Technology and information systems safeguards (e.g., patient monitoring, equipment, patient identification systems, drug alerts and IV systems, and bar coding)
- Interstate practice regulations (e.g., licensure, telehealth)
- Technology for virtual care delivery and monitoring
- Principles related to nursing workload measurement and resources and information systems
- Information literacy
- Electronic health record and physician order entry
- Decision support tools
- Role of the nurse informaticist in the context of health informatics and information systems

The Informatics and Healthcare Technologies Essentials of Master's Education in Nursing includes the following elements:

Essential V: Informatics and Healthcare Technologies
Rationale
Informatics and healthcare technologies encompass five broad areas:

- Use of patient care and other technologies to deliver and enhance care
- Communication technologies to integrate and coordinate care
- Data management to analyze and improve outcomes of care
- Health information management for evidence-based care and health education
- Facilitation and use of electronic health records to improve patient care (AACN, 2011, pp. 17–18)

Quality and Safety Education for Nurses

As nursing science evolves, it is critical that patient care improves. Sometimes, unfortunately, patient care is less-than-adequate and is unsafe. Therefore, quality and safety have become paramount. The QSEN Institute project seeks to prepare future nurses who will have the knowledge, skills, and attitudes (KSAs) necessary to continuously improve the quality and safety of the healthcare systems within which they work.

Prelicensure informatics KSAs include the following (QSEN Institute, 2014c):

INFORMATICS		
Knowledge	**Skills**	**Attitudes**
Explain why information and technology skills are essential for safe patient care	Seek education about how information is managed in care settings before providing care Apply technology and information management tools to support safe processes of care	Appreciate the necessity for all health professionals to seek lifelong, continuous learning of information technology skills
Identify essential information that must be available in a common database to support patient care Contrast benefits and limitations of different communication technologies and their impact on safety and quality	Navigate the electronic health record Document and plan patient care in an electronic health record Employ communication technologies to coordinate care for patients	Value technologies that support clinical decision making, error prevention, and care coordination Protect the confidentiality of protected health information in electronic health records
Describe examples of how technology and information management are related to the quality and safety of patient care Recognize the time, effort, and skill required for computers, databases, and other technologies to become reliable and effective tools for patient care	Respond appropriately to clinical decision-making supports and alerts Use information management tools to monitor outcomes of care processes Use high quality electronic sources of healthcare information	Value nurses' involvement in design, selection, implementation, and evaluation of information technologies to support patient care
Definition: Use information and technology to communicate, manage knowledge, mitigate error, and support decision making.		

Reproduced from Cronenwett, L., Sherwood, G., Barnsteiner J., Disch, J., Johnson, J., Mitchell, P., . . . Warren, J. (2007). Quality and safety education for nurses. *Nursing Outlook, 55*(3), 122–131. Copyright 2007, with permission from Elsevier.

Graduate-level informatics KSAs include the following (QSEN Institute, 2014b):

INFORMATICS		
Knowledge	**Skills**	**Attitudes**
Contrast benefits and limitations of common information technology strategies used in the delivery of patient care Evaluate the strengths and weaknesses of information systems used in patient care	Participate in the selection, design, implementation, and evaluation of information systems Communicate the integral role of information technology in nurses' work Model behaviors that support implementation and appropriate use of electronic health records Assist team members to adopt information technology by piloting and evaluating proposed technologies	Value the use of information and communication technologies in patient care
Formulate essential information that must be available in a common database to support patient care in the practice specialty Evaluate benefits and limitations of different communication technologies and their impact on safety and quality	Promote access to patient care information for all professionals who provide care to patients Serve as a resource for how to document nursing care at basic and advanced levels Develop safeguards for protected health information Champion communication technologies that support clinical decision making, error prevention, care coordination, and protection of patient privacy	Appreciate the need for consensus and collaboration in developing systems to manage information for patient care Value the confidentiality and security of all patient records
Describe and critique taxonomic and terminology systems used in national efforts to enhance interoperability of information systems and knowledge management systems	Access and evaluate high quality electronic sources of healthcare information Participate in the design of clinical decision-making supports and alerts Search, retrieve, and manage data to make decisions using information and knowledge management systems Anticipate unintended consequences of new technology	Value the importance of standardized terminologies in conducting searches for patient information Appreciate the contribution of technological alert systems Appreciate the time, effort, and skill required for computers, databases, and other technologies to become reliable and effective tools for patient care
Definition: Use information and technology to communicate, manage knowledge, mitigate error, and support decision making.		

This text is designed to include the necessary content to prepare nurses for practice in the ever-changing and technology-laden healthcare environments. Informatics competence has been recognized as necessary in order to enhance clinical decision making and improve patient care for many years. This is evidenced by Goossen (2000), who reflected on the need for research in this area and believed that the focus of nursing informatics research should be on the structuring and processing of patient information and the ways that these endeavors inform nursing decision making in clinical practice. The increased use of technology to enhance nursing practice, nursing education, and nursing research will open new avenues for acquiring, processing, generating, and disseminating knowledge.

In the future, nursing research will make significant contributions to the development of nursing science. Technologies and translational research will abound, and clinical practices will continue to be evidence based, thereby improving patient outcomes and decreasing safety concerns. Schools of nursing will embrace nursing science as they strive to meet the needs of changing student populations and the increasing complexity of healthcare environments.

Summary

Nursing science influences all areas of nursing practice. This chapter provided an overview of nursing science and considered how nursing science relates to typical nursing practice roles, nursing education, informatics, and nursing research. The Foundation of Knowledge model was introduced as the organizing conceptual framework for this text. Finally, the relationship of nursing science to nursing informatics was discussed. In subsequent chapters the reader will learn more about how nursing informatics supports nurses in their many and varied roles. In an ideal world, nurses would embrace nursing science as knowledge users, knowledge managers, knowledge developers, knowledge engineers, and knowledge workers.

THOUGHT-PROVOKING QUESTIONS

1. Imagine you are in a social situation and someone asks you, "What does a nurse do?" Think about how you will capture and convey the richness that is nursing science in your answer.
2. Choose a clinical scenario from your recent experience and analyze it using the Foundation of Knowledge model. How did you acquire knowledge? How did you process knowledge? How did you generate knowledge? How did you disseminate knowledge? How did you use feedback, and what was the effect of the feedback on the foundation of your knowledge?

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Objectives

1. Reflect on the progression from data to information to knowledge.
2. Describe the term information.
3. Assess how information is acquired.
4. Explore the characteristics of quality information.
5. Describe an information system.
6. Explore data acquisition or input and processing or retrieval, analysis, and synthesis of data.
7. Assess output or reports, documents, summaries, alerts, and outcomes.
8. Describe information dissemination and feedback.
9. Define information science.
10. Assess how information is processed.
11. Explore how knowledge is generated in information science.

Key Terms

- Acquisition
- Alert
- Analysis
- Chief information officers
- Chief technical officers
- Chief technology officers
- Cloud computing
- Cognitive science
- Communication science
- Computer-based information systems
- Computer science
- Consolidated Health Informatics
- Data
- Dissemination
- Document
- Electronic health records
- Federal Health Information Exchange
- Feedback
- Health information exchange
- Health Level Seven
- Indiana Health Information Exchange
- Information
- Information science
- Information systems
- Information technology
- Input
- Interfaces
- Internet2
- Internet of Things (IoT)
- Knowledge
- Knowledge worker
- Library science
- Massachusetts Health Data Consortium
- National Health Information Infrastructure
- National Health Information Network
- New England Health EDI Network
- Next-Generation Internet
- Outcome
- Output
- Processing
- Rapid Syndromic Validation Project
- Report
- Social sciences
- Stakeholders
- Summaries
- Synthesis
- Telecommunications

CHAPTER 2

Introduction to Information, Information Science, and Information Systems

Kathleen Mastrian and Dee McGonigle

Introduction

This chapter explores information, information systems (ISs), and information science as one of the building blocks of informatics. (Refer to Figure 2-1.) The key word here, of course, is *information*. Information and information processing are central to the work of health care. A healthcare professional is known as a **knowledge worker** because he or she deals with and processes information on a daily basis to make it meaningful and inform his or her practice.

Healthcare information is complex, and many concerns and issues arise with healthcare information, such as ownership, access, disclosure, exchange, security, privacy, disposal, and dissemination. The widespread implementation of **electronic health records** (EHRs) has promoted collaboration among public- and private-sector stakeholders on a wide-ranging variety of healthcare information solutions. Some of these initiatives include **Health Level Seven** (HL7), the eGov initiative by **Consolidated Health Informatics** (CHI), the **National Health Information Infrastructure** (NHII), the **National Health Information Network** (NHIN), **Next-Generation Internet** (NGI), **Internet2**, and iHealth record. There are also **health information exchange** (HIE) systems, such as Connecting for Health, the eHealth initiative, the **Federal Health Information Exchange** (FHIE), the **Indiana Health Information Exchange** (IHIE), the **Massachusetts Health Data Consortium** (MHDC), the **New England Health EDI Network** (NEHEN), the State of New Mexico **Rapid Syndromic Validation Project** (RSVP), the Southeast Michigan e-Prescribing Initiative, and the Tennessee Volunteer eHealth Initiative (Goldstein, Groen, Ponkshe, & Wine, 2007). Many of these were sparked by the HITECH Act of 2011, which set the 2014 deadline for implementing EHRs and provided the impetus for HIE initiatives.

It is quite evident from the previous brief listing that there is a need to remedy healthcare **information technology** (IT) concerns, challenges, and issues faced today. One of the main issues deals with how healthcare information is managed to make it meaningful. It is important to understand

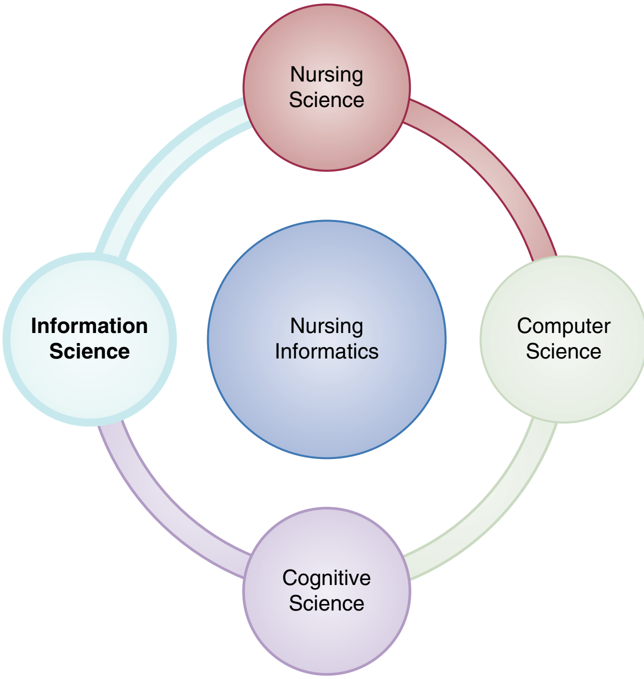

Figure 2-1 Building Blocks of Nursing Informatics

how people obtain, manipulate, use, share, and dispose of information. This chapter deals with the information piece of this complex puzzle.

Information

Suppose someone states the number 99.5. What does that mean? It could be a radio station or a score on a test. Now suppose someone says that Ms. Howsunny's temperature is 99.5°F—what does that convey? It is then known that 99.5 is a person's temperature. The data (99.5) were processed to the information that 99.5° is a specific person's temperature. **Data** are raw facts. Information is processed data that has meaning. Healthcare professionals constantly process data and information to provide the best possible care for their patients.

Many types of data exist, such as alphabetic, numeric, audio, image, and video data. Alphabetic data refer to letters, numeric data refer to numbers, and alphanumeric data combine both letters and numbers. This includes all text and the numeric outputs of digital monitors. Some of the alphanumeric data encountered by healthcare professionals are in the form of patients' names, identification numbers, or medical record numbers. Audio data refer to sounds, noises, or tones—for example, monitor alerts or alarms, taped or recorded messages, and other sounds. Image data include graphics and pictures, such as graphic monitor displays or recorded electrocardiograms, radiographs, magnetic resonance imaging (MRI) outputs, and computed tomography (CT) scans. Video data refer to animations, moving pictures, or moving graphics. Using these data, one may review the ultrasound of a pregnant patient, examine a patient's echocardiogram, watch an animated video for professional development, or learn how to operate a new technology tool, such as a pump or monitoring system. The data we gather, such as heart and lung sounds or X-rays, help us produce information. For example, if a patient's X-rays show a fracture, it is interpreted into information such as spiral, compound, or hairline. This information is then processed into knowledge and a treatment plan is formulated based on the healthcare professional's wisdom.

The integrity and quality of the data, rather than the form, are what matter. Integrity refers to whole, complete, correct, and consistent data (**Figure 2-2**). Data integrity can be compromised through human error; viruses, worms, or other computer bugs; hardware failures or crashes; transmission errors; or hackers entering the system. **Figure 2-3** illustrates some ways that data can be compromised. Information technologies help to decrease these errors by putting into place safeguards, such as backing up files on a routine basis, error detection for transmissions, and user **interfaces** that help people enter the data correctly. High-quality data are relevant and accurately represent their corresponding concepts. Data are dirty when a database contains errors, such as duplicate, incomplete, or outdated records. One author (D.M.) found 50 cases of tongue cancer in a database she examined for data quality. When the records were tracked down and analyzed, and the dirty data were removed, only one case of tongue cancer remained. In this situation, the data for the same person had been entered erroneously 49 times. The major problem was with the patient's identification number and name: The number was changed or his name was misspelled repeatedly. If researchers had just taken the number of cases in that defined population as 50, they would have concluded that tongue cancer was an epidemic, resulting in flawed information that is not meaningful. As this example demonstrates, it is imperative that data be clean if the goal is quality information. The data that are processed into information must be of high quality and integrity to create meaning to inform assessments and decision making.

To be valuable and meaningful, information must be of good quality. Its value relates directly to how the information informs decision making. Characteristics of valuable, quality information include accessibility, security, timeliness, accuracy, relevancy, completeness, flexibility, reliability, objectivity, utility, transparency, verifiability, and reproducibility.

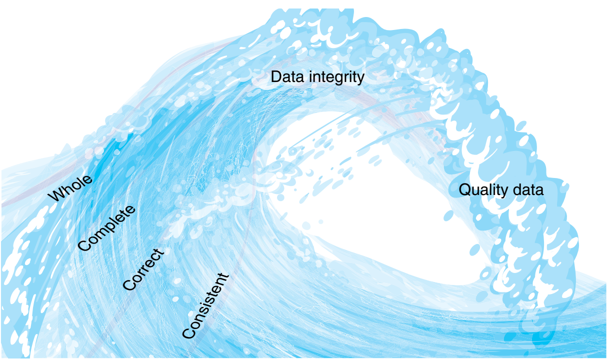

Figure 2-2 Data Integrity

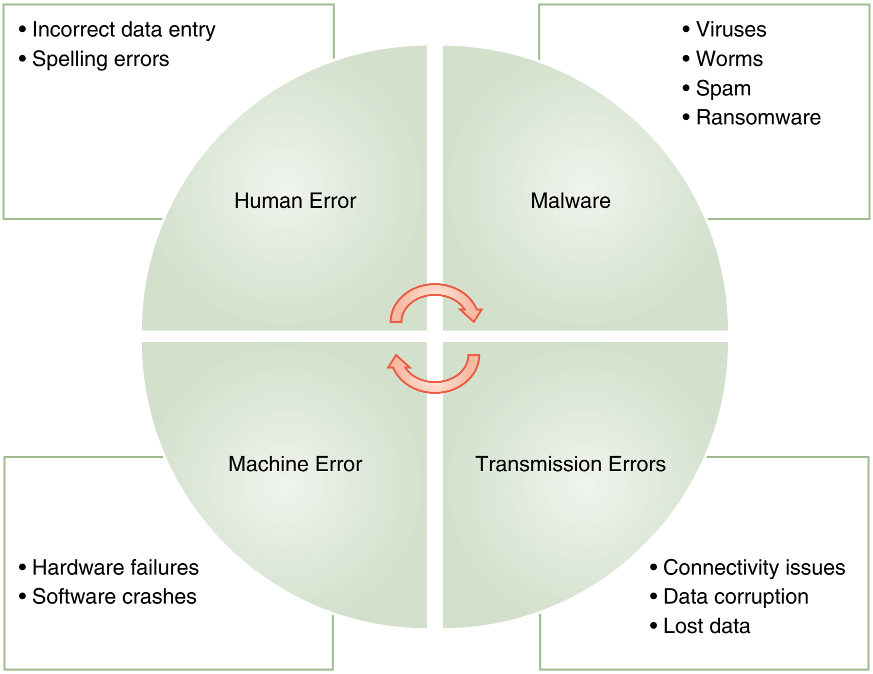

Figure 2-3 Threats to Data Integrity

Accessibility is a must; the right user must be able to obtain the right information at the right time and in the right format to meet his or her needs. Getting meaningful information to the right user at the right time is as vital as generating the information in the first place. The right user refers to an authorized user who has the right to obtain the data and information he or she is seeking. Security is a major challenge because unauthorized users must be blocked while the authorized user is provided with open, easy access (see the *Electronic Security* chapter).

Timely information means that the information is available when it is needed for the right purpose and at the right time. Knowing who won the lottery last week does not help one to know if the person won it today. Accurate information means that there are no errors in the data and information. Relevant information is a subjective descriptor, in that the user must have information that is relevant or applicable to his or her needs. If a healthcare provider is trying to decide whether a patient needs insulin and only the patient's CT scan information is available, this information is not relevant for that current need. However, if one needed information about the CT scan, the information is relevant.

Complete information contains all of the necessary essential data. If the healthcare provider needs to contact the only relative listed for the patient and his or her contact information is listed but the approval for that person to be a contact is missing, this information is considered incomplete. Flexible information means that the information can be used for a variety of purposes. Information concerning the inventory of supplies on a nursing unit, for example, can be used by nurses who need to know if an item is available for use for a patient. The nurse manager accesses this information to help decide which supplies need to be ordered, to determine which items are used most frequently, and to do an economic assessment of any waste.

Reliable information comes from reliable or clean data gathered from authoritative and credible sources. Objective information is as close to the truth as one can get; it is not subjective or biased, but rather is factual and impartial. If someone states something, it must be determined whether that person is reliable and whether what he or she is stating is objective or tainted by his or her own perspective.

Utility refers to the ability to provide the right information at the right time to the right person for the right purpose. Transparency allows users to apply their intellect to accomplish their tasks while the tools housing the information disappear into the background. Verifiable information means that one can check to verify or prove that the information is correct. Reproducibility refers to the ability to produce the same information again.

Information is acquired either by actively looking for it or by having it conveyed by the environment. All of the senses (vision, hearing, touch, smell, and taste) are used to gather input from the surrounding world, and as technologies mature, more and more **input** will be obtained through the senses. Currently, people receive information from computers (output) through vision, hearing, or touch (input); and the response (output) to the computer (input) is the interface with technology. Gesture recognition is increasing, and interfaces that incorporate it will change the way people become informed. Many people access the Internet on a daily basis seeking information or imparting information. Individuals are constantly becoming informed, discovering, or learning; becoming reinformed, rediscovering, or relearning; and purging what has been acquired. The information acquired through these processes is added to the personal knowledge base. **Knowledge** is the awareness and understanding of a set of information and ways that information can be made useful to support a specific task or arrive at a decision. This knowledge building is an ongoing process engaged in while a person is conscious and going about his or her normal daily activities.

Information Science

Information science has evolved over the last 50 or so years as a field of scientific inquiry and professional practice. It can be thought of as the science of information, studying the application and usage of information and knowledge in organizations and the interface or interaction between people, organizations, and ISs. This extensive, interdisciplinary science integrates features from **cognitive science**, **communication science**, **computer science**, **library science**, and the **social sciences**. Information science is primarily concerned with the input, processing, output, and feedback of data and information through technology integration with a focus on comprehending the perspective of the **stakeholders** involved and then applying IT as needed. It is systemically based, dealing with the big picture rather than individual pieces of technology.

Information science can also be related to determinism. Specifically, it is a response to technologic determinism—the belief that technology develops by its own laws, that it realizes its own potential, limited only by the material resources available, and must therefore be regarded as an autonomous system controlling and ultimately permeating all other subsystems of society (Web Dictionary of Cybernetics and Systems, 2007, para. 1).

This approach sets the tone for the study of information as it applies to itself, the people, the technology, and the varied sciences that are contextually related depending on the needs of the setting or organization; what is important is the interface between the stakeholders and their systems, and the ways they generate, use, and locate information. According to Cornell University (2010), "Information Science brings together faculty, students and researchers who share an interest in combining computer science with the social sciences of how people and society interact with information" (para. 1). Information science is an interdisciplinary, people-oriented field that explores and enhances the interchange of information to transform society, communication science, computer science, cognitive science, library science, and the social sciences. Society is dominated by the need for information, and knowledge and information science focus on systems and individual users by fostering user-centered approaches that enhance society's information capabilities, effectively and efficiently linking people, information, and technology. This impacts the configuration and mix of organizations and influences the nature of work—namely, how knowledge workers interact with and produce meaningful information and knowledge.

Information Processing

Information science enables the processing of information. This processing links people and technology. Humans are organic ISs, constantly acquiring, processing, and generating information or knowledge in their professional and personal lives. This high degree of knowledge, in fact, characterizes humans as extremely intelligent organic machines. The premise of this text revolves around this concept, and the text is organized on the basis of the Foundation of Knowledge model: knowledge **acquisition**, knowledge processing, knowledge generation, and knowledge dissemination.

Information is data that are processed using knowledge. For information to be valuable or meaningful, it must be accessible, accurate, timely, complete, cost-effective, flexible, reliable, relevant, simple, verifiable, and secure. Knowledge is the awareness and understanding of an information set and ways that information can be made useful to support a specific task or arrive at a decision. As an example, if an architect were going to design a building, part of the knowledge necessary for developing a new building is understanding how the building will be used, what size of building is needed compared to the available building space, and how many people will have or need access to this building. Therefore, the work of choosing or rejecting facts based on their significance or relevance to a particular task, such as designing a building, is also based on a type of knowledge used in the process of converting data into information. Information can then be considered data made functional through the application of knowledge. The knowledge used to develop and glean knowledge from valuable information is generative (having the ability to originate and produce or generate) in nature. Knowledge must also be viable. Knowledge viability refers to applications that offer easily accessible, accurate, and timely information obtained from a variety of resources and methods and presented in a manner so as to provide the necessary elements to generate knowledge.

Information science and computational tools are extremely important in enabling the processing of data, information, and knowledge in health care. In this environment, the hardware, software, networking, algorithms, and human organic ISs work together to create meaningful information and generate knowledge. The links between information processing and scientific discovery are paramount. However, without the ability to generate practical results that can be disseminated, the processing of data, information, and knowledge is for naught. It is the ability of machines (inorganic ISs) to support and facilitate the functioning of people (human organic ISs) that refines, enhances, and evolves nursing practice by generating knowledge. This knowledge represents five rights: the right information, accessible by the right people in the right settings, applied the right way at the right time.

An important and ongoing process is the struggle to integrate new knowledge and old knowledge so as to enhance wisdom. Wisdom is the ability to act appropriately; it assumes actions directed by one's own wisdom. Wisdom uses knowledge and experience to heighten common sense, and uses insight to exercise sound judgment in practical matters. It is developed through knowledge, experience, insight, and reflection. Wisdom is sometimes thought of as the highest form of common sense, resulting from accumulated knowledge or erudition (deep, thorough learning) or enlightenment (education that results in understanding and the dissemination of knowledge). It is the ability to apply valuable and viable knowledge, experience, understanding, and insight while being prudent and sensible. Knowledge and wisdom are not synonymous, because knowledge abounds with others' thoughts and information, whereas wisdom is focused on one's own mind and the synthesis of one's own experience, insight, understanding, and knowledge.

If clinicians are inundated with data without the ability to process it, the situation results in too much data and too little wisdom. Consequently, it is crucial that clinicians have viable ISs at their fingertips to facilitate the acquisition, sharing, and use of knowledge while maturing wisdom; this process leads to empowerment.

Information Science and the Foundation of Knowledge

Information science is a multidisciplinary science that encompasses aspects of computer science, cognitive science, social science, communication science, and library science to deal with obtaining, gathering, organizing, manipulating, managing, storing, retrieving, recapturing, disposing of, distributing, and broadcasting information. Information science studies everything that deals with information and can be defined as the study of ISs. This science originated as a subdiscipline of computer science, as practitioners sought to understand and rationalize the management of technology within organizations. It has since matured into a major field of management and is now an important area of research in management studies. Moreover, information science has expanded its scope to examine the human–computer interaction, interfacing, and interaction of people, ISs, and corporations. It is taught at all major universities and business schools worldwide.

Modern-day organizations have become intensely aware of the fact that information and knowledge are potent resources that must be cultivated and honed to meet their needs. Thus information science or the study of ISs—that is, the application and usage of knowledge—focuses on why and how technology can be put to best use to serve the information flow within an organization.

Information science impacts information interfaces, influencing how people interact with information and subsequently develop and use knowledge. The information a person acquires is added to his or her knowledge base. Knowledge is the awareness and understanding of an information set and ways that information can be made useful to support a specific task or arrive at a decision.

Healthcare organizations are affected by and rely on the evolution of information science to enhance the recording and processing of routine and intimate information while facilitating human-to-human and human-to-systems communications, delivery of healthcare products, dissemination of information, and enhancement of the organization's business transactions. Unfortunately, the benefits and enhancements of information science technologies have also brought to light new risks, such as glitches and loss of information and hackers who can steal identities and information. Solid leadership, guidance, and vision are vital to the maintenance of cost-effective business performance and cutting-edge, safe information technologies for the organization. This field studies all facets of the building and use of information. The emergence of information science and its impact on information have also influenced how people acquire and use knowledge.

Information science has already had a tremendous impact on society and will undoubtedly expand its sphere of influence further as it continues to evolve and innovate human activities at all levels. What visionaries only dreamed of is now possible and part of reality. The future has yet to fully unfold in this important arena.

Introduction to Information Systems

Consider the following scenario: You have just been hired by a large healthcare facility. You enter the personnel office and are told that you must learn a new language to work on the unit where you have been assigned. This language is used just on this unit. If you had been assigned to a different unit, you would have to learn another language that is specific to that unit, and so on. Because of the differences in various units' languages, interdepartmental sharing and information exchange (known as interoperability) are severely hindered.

This scenario might seem far-fetched, but it is actually how workers once operated in health care—in silos. There was a system for the laboratory, one for finance, one for clinical departments, and so on. As healthcare organizations have come to appreciate the importance of communication, tracking, and research, however, they have developed integrated **information systems** that can handle the needs of the entire organization.

Information and IT have become major resources for all types of organizations, and health care is no exception (see **Box 2-1**). Information technologies help to shape a healthcare organization, in conjunction with personnel, money, materials, and equipment. Many healthcare facilities have hired **chief information officers** (CIOs) or **chief technical officers** (CTOs), also known as **chief technology officers**. The CIO is involved with the IT infrastructure, and this role is sometimes expanded to include the position of chief knowledge officer. The CTO is focused on organizationally based scientific and technical issues and is responsible for technological research and development as part of the organization's products and services. The CTO and CIO must be visionary leaders for the organization, because so much of the business of health care relies on solid infrastructures that generate potent and timely information and

BOX 2-1 EXAMPLES OF INFORMATION SYSTEMS

Information System	How It Is Used
Clinical Information System (CIS)	Comprehensive and integrative system that manages the administrative, financial, and clinical aspects of a clinical facility; a CIS should help to link financial and clinical outcomes. An example is the EHR.
Decision Support System (DSS)	Organizes and analyzes information to help decision makers formulate decisions when they are unsure of their decision's possible outcomes. After gathering relevant and useful information, develops "what if" models to analyze the options or choices and alternatives.
Executive Support System	Collects, organizes, analyzes, and summarizes vital information to help executives or senior management with strategic decision making. Provides a quick view of all strategic business activities.
Geographic Information System (GIS)	Collects, manipulates, analyzes, and generates information related to geographic locations or the surface of the earth; provides output in the form of virtual models, maps, or lists.
Management Information Systems (MIS)	Provides summaries of internal sources of information, such as information from the transaction processing system, and develops a series of routine reports for decision making.
Office Systems	Facilitates communication and enhances the productivity of users needing to process data and information.
Transaction Processing System (TPS)	Processes and records routine business transactions, such as billing systems that create and send invoices to customers, and payroll systems that generate employees' pay stubs and wage checks and calculate tax payments.
Hospital Information System (HIS)	Manages the administrative, financial, and clinical aspects of a hospital enterprise. It should help to link financial and clinical outcomes.

knowledge. The CTO and CIO are sometimes interchangeable positions, but in some organizations the CTO reports to the CIO. These positions will become critical roles as companies continue to shift from being product oriented to knowledge oriented, and as they begin emphasizing the production process itself rather than the product. In health care, ISs must be able to handle the volume of data and information necessary to generate the needed information and knowledge for best practices, because the goal is to provide the highest quality of patient care.

Information Systems

ISs can be manually based, but for the purposes of this text, the term refers to **computer-based information systems** (CBISs). According to Jessup and Valacich (2008), CBISs "are combinations of hardware, software and telecommunications networks that people build and use to collect, create, and distribute useful data, typically in organizational settings" (p. 10). Along the same lines, ISs are also defined as "a collection of interconnected elements that gather, process, store and distribute data and information while providing a feedback structure to meet an objective" (Stair & Reynolds, 2016, p. 4). ISs are designed for specific purposes within organizations. They are only as functional as the decision-making capabilities, problem-solving skills, and programming potency built in and the quality of the data and information input into them. The capability of the IS to disseminate, provide feedback, and adjust the data and information based on these dynamic processes is what sets them apart. The IS should be a user-friendly entity that provides the right information at the right time and in the right place.

An IS acquires data or inputs; processes data through the retrieval, **analysis**, or **synthesis** of those data; disseminates or outputs information in the form of reports, documents, summaries, alerts, prompts, or outcomes; and provides for responses or feedback. Input or data acquisition is the activity of collecting and acquiring raw data. Input devices include combinations of hardware, software, and **telecommunications**, including keyboards, light pens, touch screens, mice or other pointing devices, automatic scanners, and machines that can read magnetic ink characters or lettering. To watch a pay-per-view movie, for example, the viewer must first input the chosen movie, verify the purchase, and have a payment method approved by the vendor. The IS must acquire this information before the viewer can receive the movie.

Processing—the retrieval, analysis, or synthesis of data—refers to the alteration and transformation of the data into helpful or useful information and outputs. The processing of data can range from storing it for future use; to comparing the data, making calculations, or applying formulas; to taking selective actions. Processing devices consist of combinations of hardware, software, and telecommunications and include processing chips where the central processing unit (CPU) and main memory are housed. Some of these chips are quite ingenious. According to Schupak (2005), the bunny chip could save the pharmaceutical industry money while sparing "millions of furry creatures, with a chip that mimics a living organism" (para. 1). The HμREL Corporation has developed environments or biologic ISs that reside on chips and actually mimic the functioning of the human body. Researchers can use these environments to test for both the harmful and beneficial effects of drugs, including those that are considered experimental and that could be harmful if used in human and animal testing. Such chips also allow researchers to monitor a drug's toxicity in the liver and other organs.

One patented HμREL microfluidic "biochip" comprises an arrangement of separate but fluidically interconnected "organ" or "tissue" compartments. Each compartment contains a culture of living cells drawn from, or engineered to mimic the primary functions of, the respective organ or tissue of a living animal. Microfluidic channels permit a culture medium that serves as a "blood surrogate" to recirculate just as in a living system, driven by a microfluidic pump. The geometry and fluidics of the device are fashioned to simulate the values of certain related physiologic parameters found in the living creature. Drug candidates or other substrates of interest are added to the culture medium and allowed to recirculate through the device. The effects of drug compounds and their metabolites on the cells within each respective organ compartment are then detected by measuring or monitoring key physiologic events. The cell types used may be derived from either standard cell culture lines or primary tissues (HμREL Corporation, 2010, para. 2–3). As new technologies such as the HμREL chips continue to evolve, more and more robust ISs that can handle a variety of biological and clinical applications will be seen.

Returning to the movie rental example, the IS must verify the data entered by the viewer and then process the request by following the steps necessary to provide access to the movie that was ordered. This processing must be instantaneous in today's world, where everyone wants everything *now*. After the data are processed, they are stored. In this case, the rental must also be processed so the vendor receives payment for the movie, whether electronically, via a credit card or checking account withdrawal, or by generating a bill for payment.

Output or **dissemination** produces helpful or useful information that can be in the form of reports, documents, summaries, alerts, or outcomes. A **report** is designed to inform and is generally tailored to the context of a given situation or user or user group. Reports may include charts, figures, tables, graphics, pictures, hyperlinks, references, or other documentation necessary to meet the needs of the user. A **document** represents information that can be printed, saved, emailed, or otherwise shared, or displayed. **Summaries** are condensed versions of the original information designed to highlight the major points. An **alert** is comprised of warnings, feedback, or additional information necessary to assist the user in interacting with the system. An **outcome** is the expected result of input and processing. **Output** devices are combinations of hardware, software, and telecommunications and include sound and speech synthesis outputs, printers, and monitors.

Continuing with the movie rental example, the IS must be able to provide the consumer with the movie ordered when it is wanted and somehow notify the purchaser that he or she has, indeed, purchased the movie and is granted access. The IS must also be able to generate payment either electronically or by generating a bill, while storing the transactional record for future use.

Feedback or responses are reactions to the inputting, processing, and outputs. In ISs, feedback refers to information from the system that is used to make modifications in the input, processing actions, or outputs. In the movie rental example, what if the consumer accidentally entered the same movie order three times, but really wanted to order the movie only once? The IS would determine that more than one movie order is out of range for the same movie order at the same time and provide feedback. Such feedback is used to verify and correct the input. If undetected, the viewer's error would result in an erroneous bill and decreased customer satisfaction while creating more work for the vendor, which would have to engage in additional transactions with the customer to resolve this problem. The *Nursing Informatics Practice Applications: Care Delivery* section of this text provides detailed descriptions of clinical ISs that operate on these same principles to support healthcare delivery.

Summary

Information systems deal with the development, use, and management of an organization's IT infrastructure. An IS acquires data or inputs; processes data through the retrieval, analysis, or synthesis of those data; disseminates or outputs in the form of reports, documents, summaries, alerts, or outcomes; and provides for responses or feedback. Quality decision-making and problem-solving skills are vital to the development of effective, valuable ISs. Today's organizations now recognize that their most precious asset is their information, as represented by their employees, experience, competence or know-how, and innovative or novel approaches, all of which are dependent on a robust information network that encompasses the information technology infrastructure.

In an ideal world, all ISs would be fluid in their ability to adapt to any and all users' needs. They would be Internet oriented and global, where resources are available to everyone. Think of **cloud computing**—it is just the beginning point from which ISs will expand and grow in their ability to provide meaningful information to their users. As technologies advance, so will the skills and capabilities to comprehend and realize what ISs can become. As wearable tracking technologies and other health-related mobile applications expand, more robust and timely health data will be generated, and this data will need to be processed into meaningful information. "Practitioners and medical researchers can look forward to technologies that enable them to apply data analysis to develop new insights into finding cures for difficult diseases. Healthcare CIOs and other IT leaders can expect to be called upon to manage all the new data and devices that will be transforming healthcare as we know it" (Schindler, 2015, para. 2). Devices with sensors communicating with each other is known as the **Internet of Things (IoT)** and the future possibilities for health care are tremendous. "The IoT raises the bar—enabling connection and communication from anywhere to anywhere—and allows analytics to replace the human decision-maker" (Glasser, 2015, para. 3). Essentially, the sensor-collected data are transmitted to another technology, triggering an action or an alert that prompts feedback for an action. For example, "imagine a miniaturized, implanted device or skin patch that monitors a diabetic's blood sugar, movement, skin temperature and more, and informs an insulin pump to adjust the dosage" (para. 8).

It is important to continue to develop and refine functional, robust, visionary ISs that meet the current meaningful information needs while evolving systems that are even better prepared to handle future information and knowledge needs of the healthcare industry.