Information Technology

Curricula 2017

Curriculum Guidelines for
Undergraduate Degree Programs
in Information Technology

A Report in the Computing Curricula Series

Task Group on Information Technology Curricula

Association for Computing Machinery (ACM)
IEEE Computer Society (IEEE-CS)

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Chapter 1: Introduction

In the 1980s, the Association for Computing Machinery (ACM) and the Computer Society of the Institute for Electrical and Electronics Engineers (IEEE-CS) established a joint committee to develop computing curricula (CC) guidelines for undergraduate degree programs in computing. This effort resulted into Computing Curricula 1991, also called CC'91 or CC1991 [Tuc1]. Over the years, this effort resulted in a series of documents that is ongoing even today. One of the documents that emerged was Computing Curricula Guidelines for Undergraduate Degree Programs in Information Technology, also known as IT2008 [Lun1].

This report carries the project name IT2017 and represents an evolution from its predecessor. The report is not a set of standards so its elements are not mandatory. IT2017 represents suggested guidelines for information technology (IT) programs to consider in developing futuristic programs in IT. The committee that is developing this project is the IT2017 task group. Its composition consists of twelve professionals representing academia (9) and industry (3). Its scope encompasses three continents (Asia, Europe, North America) and five countries (Canada, China, Netherlands, Saudi Arabia, United States). In addition, several professional organizations have representatives on the task group such as the Association for Computing Machinery (ACM), the Association for Information Technology Professionals (AITP), the Canadian Information Processing Society (CIPS), the IEEE Computer Society (IEEE-CS), and the Information Systems Audit and Control Association (ISACA).

1.1 Vision, Mission, and Goals

The IT2017 task group has worked diligently since 2014 and it has adopted a vision, a mission, and goals for the project. The following statement reflects the vision for the project.

> *The IT2017 report will become a sought-after and durable set of guidelines for use by educational institutions around the world to help them develop IT curricula for the next ten years!*

Likewise, the following statement expresses the mission for the project.

> *Knowledge alone is not sufficient to be productive in the changing information technology world. Therefore, since competency encompasses knowledge, ability and skill, the mission of the IT2017 project is to produce a globally accepted document of information technology competencies appropriate for undergraduate degree programs that meets the growing demands of the changing technological world and that is useful for both industry and academia.*

The vision and mission of the project have crystalized the manner in which the task group thinks and functions.

The IT2017 task group established a set of goals or objectives that form the foundation of the IT2017 project. They appear here as a listing followed by an explanation of the intent of these goals.

1. *Develop a project plan with achievable milestones that aids in completing the IT2017 project on time.*
2. *Develop a robust document that is acceptable by industry and academia.*
3. *Receive industry feedback and support for the IT2017 report.*
4. *Disseminate the IT2017 report worldwide.*
5. *Evaluate the efficacy of the IT2017 report.*

These rather ambitious goals form the operating procedure of the IT2017 task group. Underlying these goals is the effort to revise IT2008 report so that it incorporates the developments of the past nine years. Computing technologies have developed rapidly over this time in ways that have had a profound effect on curriculum design and pedagogy.

The intent of the first goal is obvious; the IT2017 task group wishes to accomplish its task accurately, on time, and within budget. This project management approach is an underlying theme on the way the task group operates. The intent of the second goal is to produce a document that both industry and academia can embrace as a legitimate entity useful to their own objectives including graduate studies. The third goal is critical; most graduates of information technology programs will seek industry positions. Industry's response to the IT2017 project would be a bellwether of its achievement. The word "success" characterizes this goal. For the fourth goal, the plan is to disseminate the final document and its interim predecessors to the widest audience possible. Considering the scope of the IT2017 task group, the achievement of this goal is paramount. Regarding the fifth goal, the task group plans a follow-up evaluation to see whether the final recommendation accomplished its intended ends.

In summary, the IT2017 report proposes a learning-centered framework for what undergraduate IT graduates should be able to do with what they know. The report articulates competencies grounded in essential and supplemental IT domain content to enable faculty members to implement IT degree programs that articulate convincingly what students should learn rather than what instructors should teach. The report draws on learning sciences and educational research and practices in competency-based education. The IT2017 task group will strengthen the case for a competency-based approach to learning.

1.2 Overall Scope of Computing

Due to the broadening scope of computing—and the feedback received from prior publications—the computing curricula initiative contains reports for several disciplines. These disciplines describe separately vital areas such as computer engineering, computer science, information systems, information technology, and software engineering, each with its own identity and pedagogical traditions.

To encompass the different disciplines that are part of the overall scope of computing, professional organizations have undertaken similar reports in five curricular areas. These areas include:

- Computer engineering (2004) and the pending CE2016 report
- Computer science (2001, 2008, 2013)
- Information systems (1997, 2002, 2006, 2010) and its ongoing endeavors
- Information technology (2008) and the current endeavor
- Software engineering (2004, 2014)

We should expect new ACM/IEEE curricular projects to emerge such as cybersecurity and data science.

As the individual reports unfold to completion, representatives from the five computing disciplines have produced an overview report called "computing curricula 2005" [Sha1] that links them together. That overview report contains descriptions of the various computing disciplines along with an assessment of the commonalities and differences that exist among them. It also suggests the possibility of future curricular disciplines in computing.

Professional organizations viewed the set of recommendations as minimal in an effort to avoid being prescriptive. Experts on computing degree program development teams have had and still have the freedom to act independently, but reports must have this commonality among them. The anticipation is that within each discipline, undergraduate degree programs will exceed this minimal set in various ways.

1.3 Structure of the IT2017 Report

This IT2017 report addresses undergraduate degree programs in information technology. The main body of the report consists of seven chapters in addition to this one. Chapter 2 discusses the way information technology evolved as a discipline. It also highlights many of the characteristics expected of information technology graduates, especially their service to the public and their expected breadth of knowledge. Chapter 3 discusses an industry perspective toward information technology. Chapter 4 highlights the importance of professionalism in the practice of information technology.

Chapter 5 presents an overview of the information technology curricular framework and describes a basis for curricular recommendations. This framework is informed by the previous discussions such as the vision, mission, and goals, the underlying principles, the perspectives from industry, and professional practice. The chapter also articulates the various IT domains of the curricular framework, differences between essential and supplemental IT domains, the number of minimal hours in an IT program, and various competencies an individual need to become an effective professional in information technology.

Chapter 6 provides a discussion on transforming competencies into a curriculum; it also discusses issues affecting the implementation of an information technology curriculum such as the arrangement of a student's program of study, inclusion of courses within the major and those in other areas of the educational experience as well as other implementation considerations. Chapter 7 discusses some challenges that may arise when creating or continuing information technology programs such as curriculum design, computing resources, and faculty issues.

The bulk of the material in the report appears as four appendices. Appendix A addresses the IT curricular framework in detail for undergraduate information technology programs. It includes all the curricular IT domains, their associated curricular subdomains, and the competencies related to each subdomain. Appendix B illustrates typical sample curricula that might appear at different academic institutions together with related mappings of essential domains and course descriptions as they might appear at different academic institutions. Appendix C provides samples of interdisciplinary information technology programs. Appendix D recognizes reviewer contributors.

It is possible to consider that a report of this type is much too complex with framework domains and associated competencies. In today's computing educational environments, it is simply not possible to list a set of courses. Information technology programs vary among institutions. Furthermore, the technological field changes rapidly and what seems important today may just be a passing fancy. Thus, it is important to prepare students for this undetermined future by establishing foundational competencies coupled with the flexibility to adapt to new situations that await them after graduation.

1.4 Guiding Principles

In formulating this document, the task group followed the following principles.

1. *The IT2017 report must be futuristic.* It is important that this report reflect the industry and academic needs for the mid-2020s – 2025 to be more precise. Programs that implement these recommendations will not produce graduates until the early- to mid-2020s. Therefore, the task group made every effort to ensure that this report has an avant-garde tone and content to achieve this intent.

2. *This document exists as part of the CC2005 series.* The first version of this document followed the format developed in other documents within this series, in particular CC2001 – Computer Science. IT2017 report made changes to the terminology in that document to describe the IT curricular framework. In particular, the IT curricular framework is organized hierarchically into three levels. The highest level of the hierarchy is the IT curricular domain, which represents a particular disciplinary domain in IT. The IT domains are broken down into subdomains, which are defined in terms of competencies.

3. *Due to the rapidly evolving nature of information technology, revisions must include longevity.* The task group established desired competencies first and allowed IT domains to follow from the competencies. Competencies describe knowledge, skills and abilities and represent the driving force in designing and implementing IT curriculum for individual degree programs in IT. Nevertheless, the task group recommends that the professional associations in information technology continue the periodic review process that allows individual curricular recommendations to be updated on a recurring basis.

4. *The IT curricular framework must continue to be flexible and remain as small as practical.* There are a large number of careers that graduates from IT programs enter. Those careers show an enormous diversity and the knowledge base and skill sets required for each consequently vary widely as well. The IT curricular framework was therefore designed in a way that gives a program considerable freedom in tailoring the curriculum to the needs of its students and other institutional stakeholders. For this purpose, the task group recommends essential competencies that *must* be met, and provide examples of Supplemental competencies for additional depth in each IT curricular domain.

5. *The guidelines must reflect aspects that set information technology apart from other computing disciplines.* The integration of different technologies and the integration of technologies into organizations are fundamental to information technology. An IT graduate must therefore acquire a skill set that enables him or her to perform integrative tasks successfully, including user advocacy skills, the ability to address cybersecurity concerns, the ability to manage complexity through abstraction, extensive capabilities for problem solving across a range of integrated information and communication technologies, adaptability, outstanding interpersonal skills, high ethical standards, and professional responsibility. The curricular guidelines must continue to reflect these pervasive themes that appear in Chapters 2 and 4.

6. *The IT curricular framework must reflect the relationship of information technology to other computing disciplines.* Although there is a significant overlap between different computing disciplines, where possible, this IT curricular framework diverges from existing computing curricula guidelines documents by focusing on competency instead of knowledge.

7. *This document aims at four-year programs offered at institutions of higher learning, but should also be applicable in other contexts.* Despite the fact that curricular requirements of IT degree programs differ from country to country, this document is intended to be useful to computing educators throughout the world. The task group has made every effort to ensure that the curricular guidelines are sensitive to national and cultural differences so that they will be internationally applicable. Furthermore, although there are distinct differences between four-year programs and other types of programs, aspects of this document are applicable to other programs. Note that ACM has already produced a two-year report for information technology [Acm4].

8. *The development of this report must be broadly based.* To be successful, the process of creating the guidelines must include participation from many different constituencies including industry, government, agencies involved in the creation of accreditation criteria for computing programs, and the worldwide range of higher educational institutions involved in IT education.

9. *This volume must go beyond IT domains and competencies to offer significant guidance in terms of implementation of the IT curricular framework.* Although it is important for this volume to articulate a broad vision of IT education, the success of any degree program depends heavily on curricular implementation details. This volume will be effective only if it defines a small set of curricular implementation examples that assemble the IT competencies and their related subdomains into reasonable, easily implemented courses. This volume must also provide institutions with advice on the practical concerns of setting up a curriculum by including sections on strategy and tactics along with technical descriptions of the curricular material.

10. *Avoiding buzz word and current jargon.* The authors of this report have made an effort to remove any hype or current jargon from the domains and competencies. For example, ‘Big Data’ has been removed and replaced with ‘Data Scalability and Analytics’ to avoid buzz words. The goal is to make the content more timeless. There is also an attempt to choose proper wording to ensure the information has current relevance while not making the terms so generic they become meaningless.

1.5 Conclusion

The IT2017 task group is hopeful that the IT2017 report will help departments create effective curricula or help them improve the curricula they already have. The IT2017 report, with its sample curricula and course descriptions, should be a guiding light for information technology education worldwide. Additionally, these guidelines do not require all students to master all details of every domain. The intent is to have students develop the fundamental concepts of a domain so they can transfer the basic ideas toward the future.

Chapter 2: The Information Technology Discipline

2.1 The Emergence of Information Technology as a Discipline

Information technology is an enormously vibrant field that emerged at the end of the last century as our society experienced a fundamental change from an industrial society to an information society. From its inception a few decades ago, computing has become the defining technology of our age, changing how we live and work. Computing technology is integral to modern culture and a primary engine behind much of the world's economic, political, and social change.

By the late 1980s personal computers had largely replaced time-shared main frames as the dominant computing paradigm in many organizations. However, as the personal computer became more powerful and more connected, it became more complex to administer and the demand for people who could "make things work" in a networked computing environment escalated. The pervasiveness of web browsers turned the computer into an effective and popular communication device and created high demand for web-based content and services. Businesses and other organizations saw a high increase in demand for web administrators and web database application developers.

The field continues to evolve at an astonishing pace. New technologies are introduced continually and existing ones become obsolete soon after they appear. The rapid evolution of the discipline has a profound effect on information technology education, affecting both content and pedagogy. For example, networking was not seen as a major topic area in the early 1990s. The lack of emphasis on networking is not particularly surprising. Networking was not yet a mass-market phenomenon and the world-wide-web was little more than an idea in the minds of its creators. Today, networking and the Web have become the underpinnings for much of our economy. They have become critical foundations of information technology, and it is impossible to imagine that four-year programs would not devote significantly more time to this topic. At the same time, the existence of the Web has changed the nature of the educational process itself. Modern networking technology enhances everyone's ability to communicate and gives people throughout the world unprecedented access to information. In most academic programs today networking technology has become an essential pedagogical branch of study.

Much of the change that affects information technology comes from advances in technology. In the last decade there has been unprecedented innovation in technologies for communication, computation, interactivity, and delivery of information. Over the last ten years the world has changed dramatically both in how people work and live. The technology of telephony and computing has created an increasingly mobile environment where communications and connectivity are expected anytime and anyplace. Society has become accustomed to connectivity that provides access to information on demand in all aspects of everyday life. Demand for connectivity to full network service anytime and anyplace has resulted in enormous growth in wireless networks in the last few years comparable to the explosive growth of the Internet in the 1990s. In short, it is the advances in computing communication technology, particularly the Internet and the world-wide-web, that have given rise to the academic field of information technology.

2.2 The Role of Information Technology within the Computing Disciplines

Information technology is a new and rapidly growing field that started as a grassroots response to the practical, everyday needs of business and other organizations. Today, organizations of every kind are dependent on information technology. They need to have computing technology systems in place. These systems must work properly, be secure, upgraded, maintained, and replaced as appropriate. Degree programs in information technology arose because degree programs in the other computing disciplines were not producing an adequate supply of graduates capable of handling these very real needs.

IT programs prepare graduates who possess the right combination of knowledge and practical expertise to solve computing technology problems in any organization that depends on information technology as well as becoming researchers and academicians. IT professionals assume responsibility for selecting computing technology products appropriate for an organization, integrating those products with organizational needs and infrastructure, and creating, adapting, and maintaining applications and services for the organization's users of IT. Examples of these responsibilities include the installation, administration, and security of computer networks; design, development, security, and management of databases; development and integration of web and mobile applications; automation of IT maintenance operations; and the planning and management of the technology lifecycle by which an organization's computing technology is configured, upgraded, and replaced.

The diagram in Figure 2.1 appears in *Computing Curricula 2005: The Overview Report*, which includes similar diagrams for all five computing disciplines along with more details about this graphical approach to describing them. The shaded area of the diagram represents the focus of typical *information technology* curricula. This area extends down most of the right edge, encompassing the application, deployment, and configuration needs of organizations and people over a wide spectrum of contexts. Across this range (from organizational information systems, to application technologies, and down to systems infrastructure), their role has significant overlap with information systems due to pronounced organizational settings. In addition, IT's shaded area goes leftwards, from application towards theory and innovation, especially in the area of application technologies. This is because IT people often develop the digital technologies organizations use for a broad mix of informational purposes, implying an appropriate conceptual foundation in relevant principles and theory.

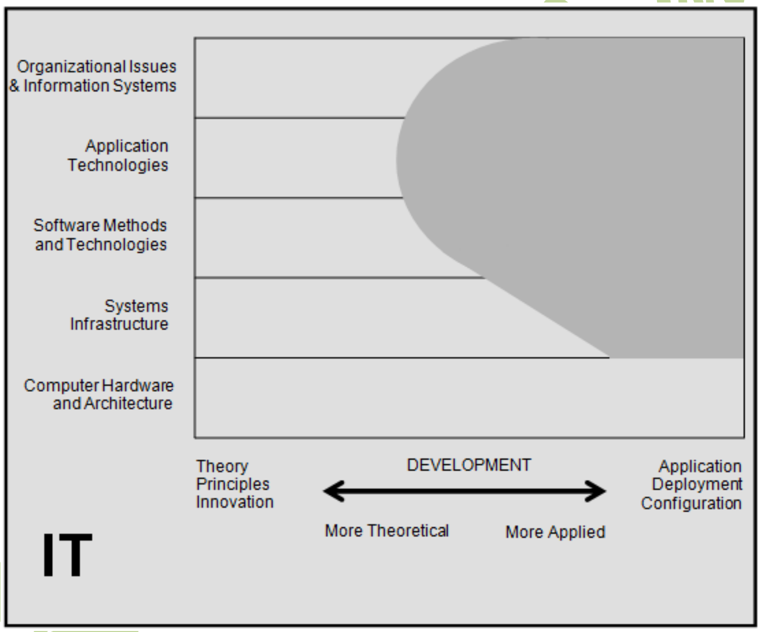

Figure 2.1 Graphic of the information technology discipline

2.3 Characteristics of an IT Graduate

The fact that information technology programs emerged to meet demand from employers has had a significant effect on the evolution of the discipline. Entry-level knowledge and skill requirements gathered from potential employers of graduates naturally translate into learning or program outcomes for graduates from information technology programs. In particular, a graduate must be able to function as a user advocate and select, create, apply, integrate and administer computing technologies to meet the needs of users within a societal and organizational context. For example, the current ABET characteristics for an information technology graduate are as follows [Abt1].

(a) Apply knowledge of computing and mathematics appropriate to the discipline
(b) Analyze a problem, and identify and define the computing requirements appropriate to its solution
(c) Design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs
(d) Function effectively on teams to accomplish a common goal

(e) Understanding professional, ethical, legal, security and social issues and responsibilities
(f) Communicate effectively with a range of audiences
(g) Analyze the local and global impact of computing on individuals, organizations, and society
(h) Recognition of the need for and an ability to engage in continuing professional development
(i) Use current techniques, skills, and tools necessary for computing practice.
(j) Use and apply current technical concepts and practices in the core information technologies.
(k) Identify and analyze user needs and take them into account in the selection, creation, evaluation and administration of computer-based systems.
(l) Integrate effectively IT-based solutions into the user environment.
(m) Understand best practices and standards and their application.
(n) Assist in the creation of an effective project plan.

The IT graduate is a problem solver or future researcher who enjoys getting technology to work effectively for the user. In the corporate environment, IT graduates use their deep understanding of how information technology works to ensure the IT infrastructure operates in a manner that is consistent with the goals and objectives of the organization. In the community, IT graduates use their familiarity with a wide range of technology hardware and software products to improve the lot of their neighbors. They may volunteer to design, configure, install or maintain a website or construct a mobile app for a charity. IT graduates are professionals trained to perform duties in an ethical manner. They are familiar with the various laws and regulations that govern the operations of the IT infrastructure they maintain. IT graduates are able to explain and justify professional decisions in a language that management and users understand. They are aware of the budget implications of technological alternatives and are prepared to defend budgets properly. IT graduates are deeply familiar with the needs and challenges involved in properly securing IT networks, applications, and websites. They seek technology solutions that robustly secure the technology without unduly adversely affecting the ability of the user to accomplish her goals. IT graduates must learn to become innovators. IT graduates must learn to figure ways to integrate new technologies into the real-world environment in manner that ensures a superior and productive experience for the user. In line with best practices in curriculum design [Sor1; Dia1], this becomes a blueprint for programs to enable its graduates to achieve these capabilities.

The academic discipline of information technology can well be characterized as the most integrative of the computing disciplines. One implication of this characteristic is graduates of IT programs should be the first to take responsibility to resolve a computing need, no matter the source or description of the problem, regardless of the solution they eventually adopt. The depth of IT lies in its breadth: IT graduates need to be broad enough to recognize any computing need and know something about possible solutions. IT graduates would be the ones to select, create or assist to create, apply, integrate, and administer the solution within the application context.

Figure 2.2 depicts an illustration the academic discipline of information technology as it appeared in the IT2008 report. The pillars of IT include programming, networking, human-computer interaction, databases, and web systems, built on a foundation of knowledge of the fundamentals of IT. Overarching the entire foundation and pillars are cybersecurity, and professionalism. This figure helped to describe the relation of the IT key components.

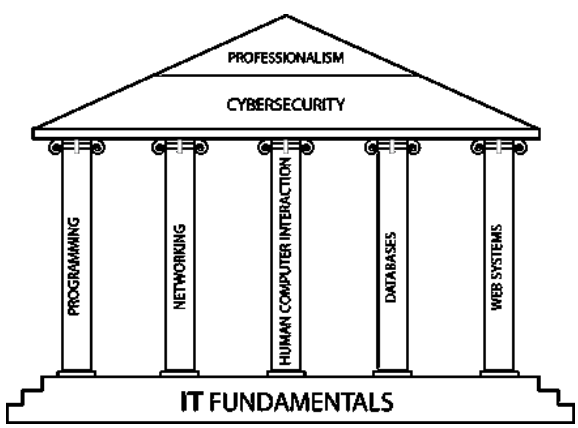

Figure 2.2: IT as depicted in the IT2008 report.

Figure 2.3 illustrates a modern version of information technology. In today's world, the suggestions of individual silos of concentration no longer exist. The pillars shown in Figure 2.2 are now mostly interwoven into a tapestry of interrelated studies and activities. Indeed, new technologies have emerged that integrate knowledge, skills, and abilities. For example, analytics and big data require data scientists where the fields of information technology (IT) and information systems (IS) work together. Each job has its own specifics. For example, extraction, transformation, loading (ETL) or data acquisition is part of IT, not IS. Data governance is also mostly an IT job.

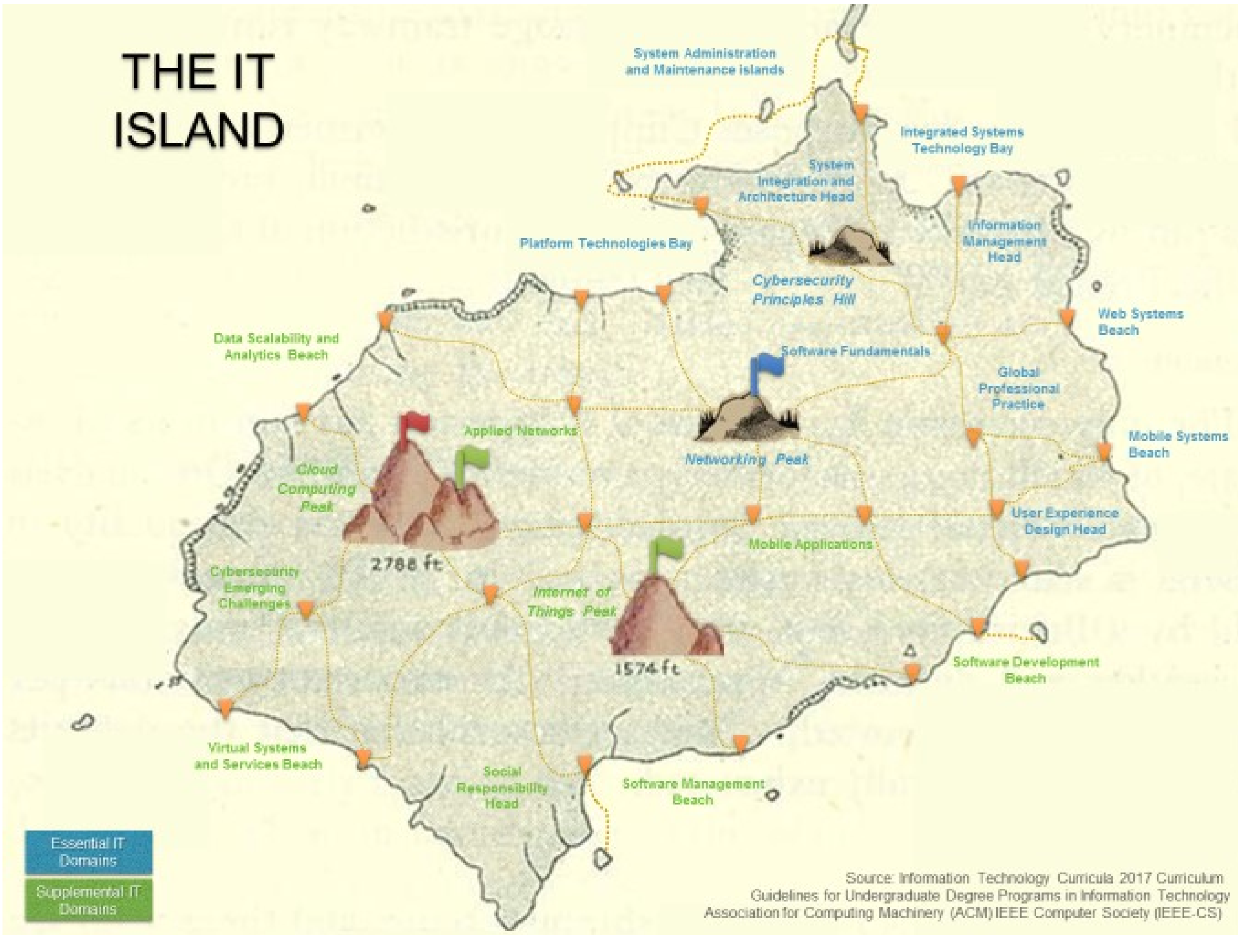

Figure 2.3: A modern illustration depicting the field of IT
[Temporary sketch by Jorge Murillo Gamboa]

It is interesting to note that this IT2017 report somewhat parallels the current predictions of the Bureau of Labor Statistics of the United States. Its 17 December 2015 report indicates the following [Bls1].

> *Employment of computer and information technology occupations is projected to grow 12 percent from 2014 to 2024, faster than the average for all occupations. These occupations are expected to add about 488,500 new jobs, from about 3.9 million jobs to about 4.4 million jobs from 2014 to 2024, in part due to a greater emphasis on cloud computing, the collection and storage of big data, more everyday items becoming connected to the Internet in what is commonly referred to as the "Internet of things," and the continued demand for mobile computing.*
>
> *The median annual wage for computer and information technology occupations was $79,390 in May 2014, which was higher than the median annual wage for all occupations of $35,540.*

Occupations include computer and information research scientists, computer network architects, computer programmers, computer support specialists, computer systems analysts, database administrator, information security analysists, and network and computer systems administrators.

2.4 Research in IT

Information technology is the newest computing discipline covered by the computing curricula volumes. And, like all the computing disciplines, it is still evolving rapidly. Given this state of affairs, this section presents comments on both the current picture of research in IT and on likely developments in the future.

In addition to the simple newness of the discipline, making definitive statements about research in IT is difficult for several reasons, including the following.

Focus on practice – IT emphasizes knowledge combined with practical, hands-on expertise. This emphasis is well matched to the challenge of successfully applying information technology in organizational and societal contexts. Many of the IT programs are undergraduate programs located at ordinary academic institutions, perhaps reflecting a greater incentive among these institutions to respond flexibly to career opportunities for graduates.

This history contrasts with disciplinary areas that emerge as research topics first, and then coalesce into disciplines. Development of a research agenda in the IT community is being informed by practice and educational programs. At this early stage in development of the discipline, this may be misinterpreted to conclude that IT lacks sufficient research potential. More accurately, the research agenda simply needs to be viewed as emerging from the practice.

The computing milieu – *The Overview Report* (CC 2005) provides one of the best efforts to date to explain the commonality and difference across a set of computing disciplines. However, it is important to realize that there is a long history of overlap, misunderstanding, and even contention among the disciplines. This is not likely to be resolved any time soon.

This intermingling can be seen along many dimensions that might be expected to separate the disciplines. While some leading journals are clearly tied to particular disciplines, other leading computing publications span multiple disciplines. Similarly, faculty members in one computing department often have research interests tied to another computing discipline.

The examination of core ideas covered by a discipline is not a completely satisfying approach to separate disciplines. In some cases, such as computer engineering, the approach works reasonably well. But for other cases, even within the disciplines, there is active discussion as to the definition of core ideas. One example related to information systems provides a useful discussion [Rei1]. Given the rapid evolution across the entire landscape of computing, this situation is not surprising, and probably healthy. On the other hand, it greatly complicates the goal of uniquely identifying research by computing discipline.

Terminology – Part of the problem of describing IT research begins with the difficulty of describing the computing domain clearly. Terms such as “computing” and “information” are badly overworked. Even more focused terms such as “programming” have different meanings from one discipline to another and they can vary in ways that are difficult to capture in any short description.

Given these considerations, the following observations seem reasonable in considering IT research.

- As a practice driven discipline, IT builds upon a rich base of existing research. A role of IT is to apply research from the other computing disciplines. Part of the research contribution of IT is to feed new questions and results back into the research streams on the foundations of which IT.
- Research unique to IT emerges from the practice of IT. IT research addresses questions related to the content of practice; that is, questions about computing. IT research also addresses questions related to the process of practice.
- IT research overlaps research in other computing disciplines. All the computing disciplines have overlaps, and IT is no exception.

Discussions within the IT community have resulted in several publications that provide initial ideas about an IT research agenda [Rei1; Eks1]. The areas identified in these early discussions include the following.

- *Integration* – Many applications of computing technologies require the integration of different system components [Eks2]. Viewing systems broadly and including people as components of systems raises a host of integration issues.
- *Trade-off analysis* – Development of IT solutions inherently requires trade-off among approaches, processes, components, and other entities. Principles and methods for conducting this analysis are needed for successful IT practice.
- *Interface issues* – Integration of system components often results in problems at the interfaces. This is true whether the interfaces involve hardware, or software, or the interface from hardware and software to people.
- *Security and assurance* – Security and information assurance have risen sharply in importance in recent years. Since protection is only as good as the weakest point in the system, security and assurance present particular challenges in IT, where the scope of concern encompasses the total system. In the 2017 revision of this document, we have chosen to refer to this area as cybersecurity.
- *Implementation* – The introduction of an IT application in a user environment often changes that environment in subtle ways. Since many IT applications are designed for the user environment as it currently exists, such changes may undermine the ability of the application to meet the needs of users. Being able to predict how an IT application is likely to change the user environment would help ensure successful design.

The list above is intended to capture some flavor of the areas that have been identified as relevant to an IT research agenda. As IT evolves as an academic discipline, areas like these will flow from the unique focus IT has on meeting the needs of users in a societal and organization context through the selection, creation, application, integration and administration of computing technologies.

Chapter 3: Industry Perspectives on Information Technology

The field of information technology (IT) has truly developed, matured, and expanded throughout industry. IT professionals apply their skills in a broad range of diverse career sectors that include business, industry, government, services, organizations, and other structured entities that use computers to automate or drive their products or services efficiently.

People seeking careers in IT have a great potential for success. A recent study by the Bureau of Labor Statistics (BLS) shows that computer occupations expect to increase by 17.7% by 2022, with information security leading by 36.5% [Bur1]. Unfortunately, although jobs are and will be available, finding qualified people to fill them is often difficult. Students graduating from technical programs such as information technology often do not have the attributes to fill the needs of industry. Perhaps they have technical skills acquired from their studies, but they may lack other skills (e.g., communication, teamwork) needed "to fit" within an industry or government environment.

3.1 The Academic Myth

Students who graduate from a four-year university program assume that the baccalaureate degree is a sufficient qualification to attain a position. This understanding may be true in some fields. Belief in this myth has stymied many a job hunter worldwide. The degree credential is likely to be necessary, but it is not a sufficient condition for a position. A general understanding exists in IT and other fields that a successful professional must be a good communicator, a strong team player, and a person with passion to succeed. Hence, having a degree is not sufficient to secure employment.

Some people believe that a graduate of an IT program who has a high grade-point-average (GPA) is more likely to attain a position than one who has a lower GPA. This is another mythical belief. A graduate having a high GPA is commendable. However, if s/he does not have the passion and drive, or does not work well in teams, or does not communicate effectively, chances are that the person will not pass the first interview.

3.2 Soft Skills

Industry managers almost unanimously agree that soft skills are a primary criterion for hiring a graduate in an IT position. Conventional wisdom among industry managers dictates that soft skills and technical skills have equal or similar value.

So, what exactly are soft skills? One definition states that soft skills are "desirable qualities for certain forms of employment that do not depend on acquired knowledge: they include common sense, the ability to deal with people, and a positive flexible attitude" [Dic2]. Another definition indicates that soft skills are "the character traits and interpersonal skills that characterize a person's relationships with other people" [Inv1]. Continuing,

> *Soft skills have more to do with who we are than what we know. As such, soft skills encompass the character traits that decide how well one interacts with others, and are usually a definite part of one's personality* [Inv1].

In the field of information technology and other fields, soft skills often complement hard skills, which are specific learned abilities such as configuring a network connection, managing a large database, installing a firewall for a local area network, or writing code in a specific language. Often we refer to these soft skills as part of social intelligence or "the ability to connect to others in a deep and direct way, to sense and stimulate reactions and desired interactions" [Soc1]. This ability to connect with co-workers in a convincing manner will be extremely important in the future. In fact, it is likely to become the distinguishing factor between those who are successful in their careers and those who are not.

While universities are well adept to teach IT hard skills, they are often at a loss in teaching or dealing with soft skills. College and university teachers simply do not have the expertise in dealing with soft skills, coupled with the fact students acquire soft skills through their upbringing and social environments, not through training. Therefore, from an industry hiring perspective, chances are that a candidate with strong soft skills will likely obtain the position.

Companies cannot teach soft skills, which are tied to an individuals' personality. However, companies can easily teach or train someone with a missing technical skill. Students and teachers should understand this reality.

3.3 Communication Skills

Industry managers also agree that communication skills are also a necessary criterion for hiring a graduate in an IT position. By communication skills, we mean "the ability to convey information and ideas effectively" [Col1]. The definition is simple; however, the meaning is deep. Almost every job seeker claims on their resume that they have excellent communication skills. So, what does it mean to have strong communication skills in the information technology field?

Despite the many attempts by universities to teach students effective communication skills, this aspect requires improvement from an industry perspective. Typically, an information technology program might require students to complete a speech class or a technical writing class, thereby believing it fulfilled its responsibility in addressing communication skills. This perception is simply not true. Taking a class might satisfy a university degree requirement, but it is not sufficient for the workplace.

In industry, good communication skills mean conveying information to people in a clear and simple manner.

> *It's about transmitting and receiving messages clearly, and being able to read your audience. It means you can do things like give and understand instructions, learn new things, make requests, ask questions and convey information with ease … [to] adapt yourself to new and different situations, read the behaviour (sic.) of other people, compromise to reach agreement, and avoid and resolve conflict … communication is a two-way street, so being a good listener is vital* [Car1].

In information technology, making a mistake because a message is misunderstood could be costly and even dangerous. Therefore, it is in the best interest of industry to hire those whose skills in communication are truly excellent. Industry cannot teach someone to become a good listener!

Those in academia should know that taking a communication course or two is not sufficient to develop effective communicators. At a minimum, reading, writing, speaking, and listening should be an embedded thread throughout the curriculum. Students need to become aware by their teachers and peers to establish a sustained practice of communication skills so by the time they graduate, they will be ready for the workplace with the skills necessary to foster greater understanding and to become more productive for their employers.

3.4 Teamwork Skills

Gone are the days when industry employees work in isolation. Even though they may have an office or a cubicle, information technology specialists must work with others from varied backgrounds and fields such as sales, engineering, artistic design, marketing, and accounting. People in these fields think differently from someone in information technology. Hence, it is necessary to understand the different dynamics that can and will occur in an industry setting.

When we think of an information technology team, we envision a group of individuals working together toward a common goal. The idea of teamwork is the "cooperative or coordinated effort on the part of a group of persons acting together as a team or in the interests of a common cause" [Dic3]. In its 1997 report on information technology, the U.S. National Science Foundation reported that the information technology student should "incorporate more learning tools (both technology- and non-technology-based) that are open-ended, inquiry-based, group/teamwork-oriented, and relevant to professional career requirements" [Wil1].

The skills necessary for useful teamwork are many; we delineate some non-prioritized attributes here. Team members must be good communicators because they must engage in a multi-way transfer of facts and ideas. They must also put aside personality issues and focus on the job at hand. Attendance and punctuality are important to be a good team player; chronic latecomers place an unnecessary burden on the team because of repetition and loss of momentum.

Team members should exercise leadership roles and volunteer to assume roles such as becoming a team leader or facilitator if the role is not pre-designated. These and other related attributes are some of the skills needed to make a team effective in achieving a shared purpose.

In the context of an information technology curriculum, working on teams is often part of course execution. It is possible that an undergraduate would experience teamwork in a number of IT courses in addition to a possible graduation or senior project. Unfortunately, these teams are often homogeneous. That is, only IT students are members of the team. Therefore, whenever possible, it is important that students from different disciplines work together on an IT team.

3.5 Technical Skills

It is natural for industry to assume that a graduate from a reputable four-year information technology program would have basic IT skills required for industry employment. The IT curricular framework expressed in Chapter 5 delineates essential and supplemental IT domains that constitute the technical education of an IT graduate.

It is important to state, however, that the essential and supplemental IT domains of the IT curricular framework are minimal for an IT degree. IT programs worldwide must establish their own niche and be responsive to surrounding industries in forming their own optimal curriculum. The quality of the graduates and their level of knowledge depend mostly on the quality of the program and institution.

From an industry perspective, hiring technically competent graduates is important, but with few exceptions, not as important as having the aforementioned soft skills accompanied by the requisite communication and team skills to ensure a competent hire. If a potential, new, or established employee lacks a particular technical skill, the employer usually allows him or her to enter a set of seminars or training sessions to achieve the missing skill.

3.6 Experience, Experience, Experience

Technical knowledge, even with the requisite soft, communication, and teamwork skills, may not be sufficient in certain industry environments without prior industry experience. This chicken-and-egg scenario has haunted university graduates for decades and centuries.

In recent years, the IT industry has been fortunate to have many opportunities for part-time or even full-time employment on a temporary basis. Such opportunities can take many forms for students. Engaging in an internship program would not only allow students to gain practical experience, but it might also allow them to gain academic credit. Another opportunity is a work-study program where students spend time working in industry for academic credit in a temporary full-time or part-time capacity. Often, this experience does not allow students to take courses, so their focus is on the practicum and not on passing exams. Any constructive experience a student can acquire is a definite plus for those seeking permanent employment upon graduation.

Often students work part-time while studying at a university. This blending of real world experience and academic endeavors provides a necessary component to help them decide on future career goals. Academia needs to embrace this experience since this is what helps differentiate one candidate from another. Experience often becomes a key component for success in achieving a position after graduation. Even though the shortage of qualified IT workers expects to continue into the 2020s, a complex interviewing scenario with much competition continues to remain for desirable positions [Chi1].

Undergraduate IT programs should explore all possibilities in bridging the experience gap between academia and industry. Developing a robust industry connection should always be a priority. For example, developing strong professional advisory board is one way to open doors with industry because members of that board will develop a bond with the program. Therefore, academic IT programs should seek all avenues with industry so their graduates have a greater chance of employment and engagement. Work with potential employers to be able to differentiate your graduates as having the 'mission-critical' or commercial product specific skills needed. Use competitions and labs to avoid graduating students who may have knowledge in the area but no hands-on skills.

3.7 IT Industry Speaks

The IT2017 task group conducted two surveys in the spring of 2015. One survey focused on industry professionals in the information technology field. The other survey addressed faculty members from computing departments. The industry survey respondents came mostly from the United States; they worked in a variety of IT departments of which, 45% were of size less than 10 people. The survey produced some interesting results, which we now summarize. Approximately 22% were from IT departments of 100 or more persons.

Regarding the type of mathematics needed for a rigorous IT program, the three most favored responses were statistics, business mathematics, and financial modeling. Probability, discrete mathematics, and linear algebra also had appeal. Regarding science needed for a rigorous IT program, 56% thought physics was the required natural science for IT students with chemistry at 25%. A few respondents noted that natural science need not be part of an IT curriculum.

Regarding the IT curricular framework (see Chapter 5), IT professionals had to select the top eight IT domains that were useful for the mid-2020s. Not surprisingly, the broad selection caused a wide range of appeal. Domains receiving among the highest marks include cybersecurity, cloud computing, and web systems. The lowest were green computing and platform technologies. Regarding IT skills for the mid-2020s, project management outpaced all other skills with a 78% appeal. Cybersecurity skills and soft skills followed in second and third place at 73% and 64%, respectively.

The task group was delighted to see that one-third of the respondents to the industry survey indicated their willingness to volunteer and help the IT2017 project. This is heartening since almost all IT graduates choose to join industry rather than going to graduate school.

In analyzing the results further, it is apparent that the emphasis on soft skills—65%—corresponds directly to the top skill set that industry professionals envision as most important—*project management*. This skill set requires excellent interpersonal, team and communication skills. Additionally, it relies on soft skills and teamwork discussed in sections 4.2 and 4.4. Project managers, are valued more for these qualities than their technical skills. Industry thinking is that an adaptive individual can learn any required technical skills.

3.8 Next Steps

As students prepare for their future career, an important consideration is their ability to be able to transition from an academic environment to a career within a corporation, organization, academic institution, or even an entrepreneurial environment. One can appreciate what a difficult transition this can be if an individual has not received the proper mix of both technical and soft skills exposure during their academic career.

Adaptability is a personality trait that is especially important within the IT industry, and will be very important for career success in the future. We find that adaptability describes the ability "to adjust oneself readily to different conditions" [Dic1]. Employees will find the ability to learn new technologies and embrace change to be of considerable importance in years to come. Georgia Nugent states, "It's a horrible irony that at the very moment the world has become more complex, we're encouraging our young people to be highly specialized in one task. We are doing a disservice to young people by telling them that life is a straight path. The liberal arts are still relevant because they prepare students to be flexible and adaptable to changing circumstances" [Seg1]. The IT industry has historically appealed to individuals who thrive in this environment of constant change.

In addition to focusing on the industry and gaining valuable work experience while attending a university, it is important that students nearing graduation are ready for important interviews by structuring their resumes into a format that highlights their technology background. What distinguishes a technical resume from a standard one is the emphasis on attributes such as specific technical skill sets and industry certifications. Monster.com, a leading job board and career site, is a good source for examples of how to create a technical resume [Mon1]. “Monster.com is one of the most visited employment websites in the United States and one of the largest in the world” [Wik1].

Being able to handle a successful interview is a career skill that is essential for students to practice and master in the course of their academic studies. It is as important as learning basic technical subjects. If students are unable to handle the rigors of a career interview, their academic GPA and various scholastic achievements will fail them in achieving the desire goal of a useful IT education—to graduate and secure a position that can lead to career fulfillment and growth.

As mention in section 3.6, an IT advisory board can help provide students with important networking within the IT industry that will also help them to perform successfully in the interviewing process. Often, IT advisory boards act as mentors to students, giving them valuable feedback on their resumes and academic background. They will often aid and encourage students to work in internships, the value of which is also a topic for discussion. Additionally, the importance of soft skills and getting along in a team environment are all components of good networking. To continue and advance in one’s career in the future, the ability to network and find career opportunities will become a very important skill.

In conclusion, the field of information technology has truly developed and it has thrived within industry. IT professionals face daily challenges to apply their skills to help businesses grow and prosper. Those students with the right skill sets who have an ability to handle changing environments and who have current technical skills will flourish and be successful within IT. Academic institutions have a responsibility to their students to enable them to gain all the skill sets needed to navigate and be successful in an evolving IT field.

Chapter 4: Professional Practice

As the field of computing continues to change, an unprecedented opportunity exists to make professional practice a seamless part of the curriculum in information technology and other computing disciplines. Understanding professional practice is critical for most students in information technology since the vast majority will enter the workforce upon graduation.

Exploration of various strategies for incorporating professional practice into the information technology (IT) curriculum is possible. The individual sections of this chapter review the underlying rationale, current practice in education, support for professional practice from both the private and public sector, techniques for incorporating professional practice into a curriculum, and strategies for assessing the effectiveness of those techniques.

4.1 Rationale

It is important to incorporate professional practice into the curriculum because graduates of information technology (IT) programs will face real-world issues in the workplace such as the needs of the public and private sector, the public's demand for higher quality products, the increasing number of computing liability cases, and the need to promote lifelong learning. In most cases, students enter school without a complete knowledge or appreciation for these issues, which is a source of frustration both for those who teach these students and for those who hire them. Indeed, as students learn more about professional practice and its underlying issues, they become more interested in their studies and ways they can work well with others. Therefore, incorporating professional practice into the curriculum can serve as a catalyst to stimulate and broaden a student's interest in computing.

Both the private and public sectors have a stake in students learning professional practice. They find that students who have experience with the realities of professional work understand the value of interpersonal skills in collaborating with team members and clients, maintain their focus on producing high-quality work, adhere to strong ethical convictions, contribute their time and talents to worthy outside causes, engage in lifelong learning, and participate in improvements in their organizations. (See Chapter 3 on Industry Perspectives of this report for a more in-depth discussion related to employer-graduate-student connections.)

The growing demand for better, less defect-ridden products has also increased the pressure to incorporate professional practice into the curriculum. For example, haphazard web-system design techniques are widely recognized as significant factors in producing web systems with a large number of defects. As a result, clients are demanding proof of sound software processes before they will sign a contract with a web system provider. Students need to understand the value of establishing face-to-face relationships with clients, agreeing to implementable requirements, and producing the highest quality systems possible.

Professional member associations and organizations promote the development of professional responsibility in several ways.

- They develop and promote codes of ethics such as the ACM Code of Ethics and Professional Conduct [Acm1], the Association of Information Technology Professionals (AITP) Code of Ethics and Standards of Conduct [Ass1], the IEEE Code of Ethics [Iee1], and the Software Engineering Code of Ethics and Professional Practices (SEEPP) [Sof1] to which members must adhere. These codes, in general, promote honesty, integrity, maintenance of high standards of quality, leadership, support of the public interest, and lifelong learning.
- They sponsor established subgroups such as the Special Interest Group on Computers and Society (SIGCAS) and the Society on Social Implications of Technology (SSIT) that focus directly on ethical and professional issues [Acm3; Iee2].
- They develop and refine curricular guidelines such as the ones in this report and its predecessors.
- They participate in the development of accreditation guidelines that ensure the inclusion of professional practice in the curriculum.
- They support the formation of student chapters that encourage students to develop a mature attitude toward professional practice.

- They provide opportunities for lifelong professional development through technical publications, conferences, and tutorials.

IT programs should inform both students and society about what they can and should expect from people professionally trained in the computing disciplines. Students, for example, need to understand the importance of professional conduct on the job and the ramifications of negligence. They also need to recognize that the professional societies, through their codes of ethics and established subgroups emphasizing professional practice, can provide a support network that enables them to stand up for what is ethically right. By laying the groundwork for this support network as part of a four-year program, students can avoid the sense of isolation that young professionals often feel and be well equipped to practice their profession in a mature and ethical way.

4.2 Current Practice in Education

Many strategies currently exist for incorporating professional practice into the curriculum. Among the most common characteristics of these strategies are courses that help students strengthen their communication, problem-solving, and technical skills. IT programs could foster these skills in computing courses. Alternatively, programs in experiences outside information technology departments such as in a speech class from a communication department or a technical writing class in an English department. Students may acquire these skills through either general education requirements or courses required specifically for information technology. Additionally, students should apply these skills in their later courses.

The scope and depth of professional practice integrated in the program curriculum varies depending on institutional commitment, departmental resources, and faculty interest. With the growing emphasis on professionalism in accreditation settings, it is likely that other schools will strengthen their commitment to teaching professional practice.

The following list outlines several potential mechanisms for incorporating additional material on professional practice.

- *Senior Capstone Courses*: These courses typically form a one- or two-semester sequence during a student's final year. Usually, students must work in teams to design and implement projects. Often, those projects involve consideration of real-world issues including cost, safety, efficiency, and suitability for the intended user. Students could develop projects may be developed solely for the class, but may also involve other on- or off-campus clients. Although the emphasis of the course is on project work and student presentations, some material on intellectual property rights, copyrights, patents, law, and ethics may be included.

- *Professionalism, Ethics, and Law Courses*: These courses are usually one semester long and they expose students to issues of professional practice, ethical behavior, and computer law, geographical limits of the jurisdiction of different country courts. Relevant curricular content may be history of computing, impact of computers on society, computing careers, legal and ethical responsibilities, international computer laws and the computing profession.

- *Practicum/Internship/Co-op Programs*: These programs are sponsored by the institution (preferably) or department to allow students to have the opportunity to work in industry full- or part-time before graduation. Having adequate administrative support for such programs is essential to their success. Students typically work during the summers and/or from one to three semesters while they are engaged in their four-year degree. The students who do a co-op or internship generally do so off campus and so may interrupt their education for a summer or a semester. Students usually receive payment for their work, but in some cases may also receive course credit.

- *Team-based Implementation Courses*: These courses emphasize the process of IT system development and typically include a team project. Course competencies include development processes, project management, economics, risk management, requirements engineering, design, implementation, maintenance, software and hardware retirement, system quality assurance, ethics, and teamwork.

- *Trends and Change in IT Industries*: Many new types of work have emerged in recent years such as security specialists, front-end web designers, creators of new GUI designs for applications, and cloud computing operators. IT programs could provide lectures or seminars that would help students understand the job market so they will be able to transfer skills to future job positions. Graduates need to adapt from traditional activities when faced with change. For example, they may face challenges with industry 4.0 or with internet plus.

- *Entrepreneurial Innovation Courses*: The IT industry needs disruptive innovation and companies to provide new technologies and more job opportunities. These courses discuss the basics every manager needs to organize successful technology-driven innovation in established firms, which will integrate creativity and design thinking in the business functions of engineering, management, communication and commerce. The students will evaluate, research, write, and present business plans using their knowledge of the entrepreneurial process.

Many courses outside information technology departments can also help students to develop stronger professional practice. Such courses include, but are not limited to, philosophical ethics, psychology, business management, economics, technical communications, and engineering design.

4.3 Supporting Professional Practice

Support for the inclusion of more professional practice in the curriculum can come from many sources. The following highlights the responsibilities of the public and private sectors, the relationship between academic preparation and the work environment, and the roles of university administrations, faculty, and students in making professional practice an educational priority.

4.3.1 Private and Public Sectors

Most students graduating from universities go on to employment in the private or public sector. In their role as the primary consumer of graduating students, industry and government play an important role in helping educational institutions promote professional practice. As an example, students who take advantage of industrial co-ops or government internships may mature faster in their problem-solving skills and become more serious about their education. Such internships may also help the institutions that offer them, in that a student who has an internship with a company may choose to work there again after graduation. With private/public sector support, integration of professional practice provides a necessary augmentation both inside and outside the classroom.

One of the most important ways that the private and public sectors can support the education process is to encourage their employees to play a greater role in helping to train students. These employees can offer support in a number of ways:

- They can function in the role of mentors to students working on projects.
- They can give special presentations to classes telling students and faculty about their firm, their work, and their development processes.
- They can take part-time positions as adjunct instructors to strengthen a university's course offerings.
- They can provide in-house training materials and/or classes to faculty and students in specialized research, process, or software tool areas.
- They can serve on industrial advisory boards, which service allows them to provide valuable feedback to the department and institution about the strengths and weaknesses of the students.

In each of these ways, institutions in the private and public sectors can establish important lines of communication with the educational institutions that provide them with their future employees.

In addition to the various opportunities that take place on campus, industry and government could also contribute to the development of strong professional practice by bringing students and faculty into environments outside of academia. Students and faculty may take field trips to local firms and begin to establish better relationships. Over a longer term, co-op, practicum, and internship opportunities give students a better understanding of what life on the job will be like. In addition, students may become more interested in their studies and use that renewed interest to increase their marketable potential. Students may also form a bond with particular employers and be more likely to return to that firm after graduation. For faculty, consulting opportunities establish a higher level of trust between the faculty member and the company. Because of these initiatives, employers, students, and faculty know more about each other and are more willing to promote each other's welfare.

In what remains one of the most important forms of support, private and public sectors may also make donations or grants to educational institutions and professional societies in the form of hardware, software, product discounts, money, time, and the like. Often, these donations and grants are critical in providing updated resources, such as lab hardware and software, and in funding student scholarships/awards as well as faculty teaching/research awards. They serve to sponsor student programming, design, and educational contests. Grants can enable more research and projects to occur. At this level, private/public sectors help to ensure the viability/progress of future education and advances in the computing field.

Through patience, long-term commitment, understanding of each other's constraints, and learning each other's value systems, institutions in the private/public sector and in education can work together to produce students skilled in professional practice and behaviors. Their cooperative agreement is essential for producing students who value a high ethical standard and the safety of the people who use the products the students will develop as professionals.

4.3.2 Modeling Local and International Work Environments

Just as industry representatives increasingly seek graduates who are "job ready," most students expect to practice computing in the workplace upon graduation without significant additional training. Although the educational experience differs from that of the workplace, educators need to ease the transition from academia to the business world by:

- Mimicking the computing and networking resources of the work environment
- Teaching students how to work in teams
- Explaining the concepts of cultural intelligence
- Providing significant project experiences

Introducing these points into the curriculum makes it possible to model significant issues in the local and international work environment. Faculty can discuss and have students apply international, intercultural, and workplace issues within the context of computing resources, teamwork, and projects.

Because computing and networking environments change rapidly and several different ones exist, it is not possible to predict the exact environment that students will use upon graduation. As a result, it is not advisable to focus attention in the curriculum on a particular set of tools. Exposure to a wide variety of computing platforms and web system tools provides good preparation for professional work, resulting in flexible learners rather than students who immaturely cling to their one familiar environment.

Learning how to work in teams is not a natural process for many students, but it is nonetheless extremely important. Students should learn to work in both small and large teams so that they acquire planning, budgeting, organizational, and interpersonal skills. Ample course material should support the students in their teamwork. The course material may include project scheduling, communication skills, the characteristics of well-functioning and malfunctioning teams, and sources of stress for team environments.

We can base assessment on the result of a team's work, the individual work of the members, or some combination thereof. Team member behavior may also play a factor in the assessment. Significant project experiences can enhance the problem-solving skills of students by exposing them to problems that are not well defined or that do not have straightforward solutions. Such projects may be a controlled, in-class experience or have a certain amount of unpredictability that occurs with an outside client. The project should serve to stretch the student beyond the typical one-person assignments that exercise basic skills in an IT domain. Beyond that, projects can also cut across several IT domains, thereby helping students to bring all their basic skills together.

4.3.3 Administration, Faculty, and Student Roles

At the highest institutional level, the administration must support faculty professional and departmental development activities. Such activities may include consulting work, professional society and community service, summer fellowships, obtaining certifications and professional licensure, achieving accreditation, forming industrial advisory boards with appropriate charters, establishing co-op/internship/practicum programs for course credit, and creating more liaisons with the private and public sectors. Such activities can be extremely time-consuming. They are, however, enormously valuable to both the individual and the institution, which must consider these activities in decisions of promotion and tenure.

Faculty and students can work together by jointly adopting, promoting, and enforcing ethical and professional behavior guidelines set by professional societies. Faculty should join professional societies and help to establish student chapters of those societies at their institutions. Through student chapters, faculty can give awards for significant achievement in course work, service to the community, or related professional activities. In addition, student chapters may provide a forum for working with potential employers and be instrumental in obtaining donations, speakers, and mentors from outside the institution.

4.4 Incorporating Professional Practice into the Curriculum

The incorporation of professional practice must be a conscious and proactive effort because much of the material blends into the fabric of existing curricula. For example, the introductory courses in the major can include discussion and assignments on the impact of computing and the internet on society and the importance of professional practice. As students progress into their second year courses, they can start to keep records of their work as a professional might do in the form of requirements, design, and test documents.

Additional material such as computer history, digital libraries, search techniques, techniques for tackling ill-defined problems, teamwork with individual accountability, real-life ethical issues, standards and guidelines, legal constraints and requirements, and the philosophical basis for ethical arguments may also appear either in a dedicated course or distributed throughout the curriculum. The distributed approach has the advantage of presenting this material in the context of a real application area. On the other hand, the distributed approach can be problematic in that teachers often minimize professional practice in the scramble to find adequate time for the technical material. Projects, however, may provide a natural outlet for much of this material particularly if faculty members can recruit external clients needing non-critical systems. When they engage in service-learning projects in the community or work with external clients, students begin to see the necessity for ethical behavior in very different terms. As a result, those students learn much more about ways to meet the needs of a client's ill-defined problem. However, no matter how teachers integrate professional practice into the curriculum, it is critical that they reinforce this material with exercises, projects, and exams.

For departments with adequate numbers of faculty members and resources, courses dedicated to teaching professional practice may be appropriate. These courses include those in professional practice, ethics, and computer law, as well as senior capstone and other appropriate courses. Additionally, more advanced courses on system economics, quality, safety, and security may be part of the experience. These courses could come from disciplines outside of information technology and they would still have a profound effect on the professional development of students.

4.5 Assessing Professional Practice Work

Faculty members can promote the positive assessment of professional practice work by establishing an infrastructure where the evaluation of student work falls under common standards that encourages the professional completion of assigned work. The infrastructure may include the following elements.

- Using competency-based assessment
- Reviewing assignments, projects, and exams for appropriate inclusion of professional practice material

- Critically reviewing and establishing sound measurements on student work to show student progress and improvement
- Getting students involved in the review and assessment process so that they obtain a better sense of the assessment process
- Employing professionals in the private and public sectors to help assess student project work
- Using standardized tests to measure overall student progress
- Taking post-graduation surveys of alumni to see how well alumni thought their education prepared them for their careers
- Obtaining program accreditation to demonstrate compliance with certain education standards for professional practice
- Synchronizing course labs with employer needs to make sure students learn job skills required by employers

The assessment process should encourage students to employ good technical practice and high standards of integrity. It should discourage students from attempting to complete work without giving themselves enough time or in a haphazard manner such as starting and barely completing work the night before an assignment is due. The assessment process should hold students accountable on an individual basis even if they work collectively in a team. It should have a consistent set of measurements so students become accustomed to using them and they learn how to associate them with their progress.

4.6 Certifications

The task group acknowledges the value of vendor and industry certifications and it encourages students to pursue them as they see necessary. Programs that offer academic credit for the completion of such certifications or for training exclusively designed to prepare for these certifications must ensure the technical knowledge gained also covers all relevant competencies defined in this document. Institutions that offer certification training must also ensure that the instructors have the credentials to operate within an institution of higher learning. Many vendor-specific certifications are practice-oriented and highly technical in nature, which is in contrast to the theory and concepts an undergraduate program should deliver. Therefore, institutions must ensure that the content meets the competencies necessary for a university degree in information technology.

Chapter 5: Information Technology Curricular Framework

The IT2008 report established a core IT curriculum founded on five pillars that include databases, networking, programming, human-computer interaction, and web systems. Security is a thread that weaves throughout the entire IT curriculum. This model has held well for the past decade and more, but it is time to revisit it. Additional core IT content areas in the IT2008 report included specific mathematics requirements, professionalism, IT fundamentals, and IT electives. These IT content areas also require a revisit. The inclusion of newly emerged IT domains in social media, big data, the internet of things, and other domains also require special consideration.

What follows is a development of an IT Curricular Framework (CF). After much discussion and interaction, it became clear that a futuristic proposal of IT competencies should have a broad basis for reference. These competencies should not emerge simply from a task group. Rather, the IT basis should include a panorama of the IT discipline itself (Chapter 2), industry perspectives (Chapter 3), and professional practices (Chapter 4). These premises should inform any set of competencies developed for a curriculum leading to an information technology degree.

5.1 Structure of the IT Curricular Framework

The IT Curricular Framework has a three-level hierarchical structure. The highest level of the hierarchy is the IT domain that represents a particular disciplinary subfield in IT, *not* a course. The IT domains are broken down into subdomains, with an identifying numeric suffix to the domain identification; as an example, ITE-NET-2 is a subdomain within the network domain (see section 5.1.3 for more details). We then describe each subdomain by a set of competencies that represent the lowest level of the hierarchy. Some competencies are dependent or are prerequisite to other competencies. This report does not distinguish such dependencies. For example, problem solving strategies, testing and iterative refinement, and the use of patterns and data and procedural abstractions create a learning environment that scaffolds programming practice.

5.1.1 Essential and Supplemental Domains

One of the goals in updating IT2008 report is to keep the implementation requirements of the IT curricular framework as small as possible. This allows programs in information technology to be as flexible as possible. To implement this principle, a distinction among the IT domains occurs by identifying those that are essential to the curriculum compared to those that are supplemental. Essential domains encompass competencies that anyone obtaining a four-year degree in the field *must* acquire. Supplemental domains encompass competencies that reflect expectations for domains where students do specialized work according to the goals of a program. All degree programs should require students to achieve some subset of the supplemental competencies. Supplemental domains give IT programs more directed choices and flexibility.

In discussing the IT2017 recommendations during their development, it is helpful to emphasize the following points:

- The essential domains refer to those competencies that all students in all information technology degree programs must achieve. Several competencies that are important in the education of many students are not included in the essential part. This absence among the essential domains does not imply a negative judgment about their value, importance, or relevance to the curriculum. Rather, it simply means that there was not a broad consensus that the domain competencies should be required of every student in all degree programs in information technology.
- The essential domains do *not* produce a complete curriculum. It is a minimal that must appear in a complete four-year curriculum.
- Programs must supplement the implementation of the essential IT curricular domains with supplemental domains. Every four-year program must include some material relevant to supplemental domains from the IT curricular framework. The selection and further expansion of supplemental domains should reflect the purpose and goals of individual IT programs.
- It is not necessary for a program to implement the essential IT domains within a set of introductory courses early in the four-year curriculum. Many of the competencies defined within the essential IT domains are

indeed introductory. However, a program can achieve some essential IT domain competencies only after students have developed significant background in their studies.

5.1.2 Learning Hours

To give readers a sense of the time requirements for learning the IT domain content and practices, this report follows a similar pattern used in some other curricula reports. IT2017 task group defines one "learning hour" as a 50-minute unit period in which the instructor facilitates learning activities that engage all students participating in that unit.

To dispel any potential confusion, it is important to underscore the following observations about the use of learning hours as a measure.

- Traditionally, a 50-minute unit period is a face-to-face class that meets for 50 minutes. The use of online educational technologies, however, allows instructors to combine face-to-face and online instructional hours or facilitate a fully online learning experience for their students.
- Even though we have used a metric with its roots in a lecture-oriented form of education, the task group believes that instructors will use active learning pedagogies to effectively engage all students with the IT domain content. The time specifications should serve as a comparative metric, in the sense that 5-hour instructional hours will presumably take approximately five times as much time as a 1-hour instructional hours, independent of the learning activities that instructors design and facilitate for their students.
- It is customary to include laboratory experiences in information technology settings. These experiences often include one hour (50 minutes), two hours (100 minutes), or three hours (150 minutes) of laboratory time. The conversion from laboratory hours to credits varies by institution. In general, laboratory times convert to the equivalent of one credit.
- The hours specified do not include the instructor's preparation time or the students' studying time.
- To ensure program flexibility, the hours listed for learning particular IT subdomains represent a *minimum* level of instructional hours. Instructors should interpret the time measurements as the minimum amount of time necessary to enable a student to achieve related competencies for that curricular subdomain. It is always appropriate to allocate more instructional hours on a curricular subdomain than the recommended minimum.

5.1.3 Tags for IT Domains

All IT domains contain identifying tags. These tags always contain the prefix "IT_" to distinguish them from IT domains related to other computing curricula reports. We use "ITE" for essential IT domain, "ITS" for supplemental IT domain, and "ITM" for related IT mathematics. Each IT domain has a three-letter abbreviation such as IOT for internet of things or NET for networks. As a result, we identify each domain by two parts separated by a hyphen. For example, we use ITE-UXD to represent "user experience design" as an essential IT domain, ITS-VSS for "virtual systems and services" as a supplemental IT domain, and ITM-DSC for "discrete structures" as a mathematical domain.

5.2 Summary of the IT Curricular Framework

A summary of the IT curricular framework appears in Tables 5.1 below. Table 5.1a describes the essential IT domains; Table 5.1b describes the supplemental IT domains. The tables show the IT domains, their subdomains, and the minimum time required for each subdomain expressed in learning hours shown in brackets. Tags differentiate the different items. For example,

ITE-IMA-05 Data organization architecture [8]

indicates that "data organization architecture" should have a relative emphasis measured by eight learning hours; it belongs to the fifth subdomain of the "information management" domain, which is essential for an information technology degree program.

Note for the supplemental domains, Table 5.1b indicates that a program should select IT domains that accumulate to at least 130 hours from the recommended domains. The total of 290 essential hours plus the 130 supplemental hours becomes 420 minimal hours in information technology content. Section 5.4 provides a rationale for the 420 hours.

The IT domains listed in Table 5.1b are a result of industry and faculty surveys as well as presentations to information technology communities. Nothing in this report prevents a program from increasing the depth of a supplemental domain or from including a new supplemental domain consistent with the goals of the program. In fact, the IT2017 effort encourages such activities.

Table 5.1a: Essential IT Domains
(290 Essential Hours)

Proposed Essential IT Domains and Hours	
ITE-NET Networking [35 hours] ITE-NET-01 History and overview [1] ITE-NET-02 Foundations of networking [3] ITE-NET-03 Physical layer [5] ITE-NET-04 Networking and interconnectivity [7] ITE-NET-05 Routing and switching [6] ITE-NET-06 Application networking services [5] ITE-NET-07 Network management and security [8]	**ITE-WMS Web and Mobile Systems** [25 hours] ITE-WMS-01 History and overview [1] ITE-WMS-02 Technologies [5] ITE-WMS-03 Digital media [5] ITE-WMS-04 Applications concepts [5] ITE-WMS-05 Development Frameworks [4] ITE-WMS-06 Vulnerabilities [3] ITE-WMS-07 Social software [2]
ITE-IMA Information Management [40 hours] ITE-IMA-01 History and overview [1] ITE-IMA-02 Data-information concepts [6] ITE-IMA-03 Data modeling [9] ITE-IMA-04 Database query languages [9] ITE-IMA-05 Data organization architecture [8] ITE-IMA-06 Special-purpose databases [2] ITE-IMA-07 Managing the database environment [5]	**ITE-SWF Software Fundamentals** [30 hours] ITE-SWF-01 History and overview [1] ITE-SWF-02 Concepts and techniques [5] ITE-SWF-03 Problem-solving strategies [3] ITE-SWF-04 Program development [8] ITE-SWF-05 Fundamental data structures [4] ITE-SWF-06 Algorithm principles [6] ITE-SWF-07 Modern app programming [3]
ITE-SIA System Integration and Architecture [20 hours] ITE-SIA-01 History and overview [1] ITE-SIA-02 Requirements [4] ITE-SIA-03 System architecture [2] ITE-SIA-04 Acquisition and sourcing [4] ITE-SIA-05 Testing and quality assurance [4] ITE-SIA-06 Integration and deployment [5]	**ITE-SAM System Administration and Maintenance** [20 hours] ITE-SAM-01 History and overview [1] ITE-SAM-02 Administrative activities [5] ITE-SAM-03 Administrative domains [4] ITE-SAM-04 Performance analysis [3] ITE-SAM-05 Backup and recovery [3] ITE-SAM-06 Applications of system administration [4]
ITE-PFT Platform Technologies [15 hours] ITE-PFT-01 History and overview [1] ITE-PFT-02 Operating systems [7] ITE-PFT-03 Computing infrastructures [2] ITE-PFT-04 Architecture and organization [3] ITE-PFT-05 Application Execution Environment [2]	**ITE-IST Integrated Systems Technology** [20 hours] ITE-IST-01 History and overview [1] ITE-IST-02 Data mapping and exchange [4] ITE-IST-03 Intersystem communication protocols [4] ITE-IST-04 Integrative programming [4] ITE-IST-05 Scripting techniques [4] ITE-IST-06 Defensible integration [3]
ITE-CSP Cybersecurity Principles [40 hours] ITE-CSP-01 History and overview [1] ITE-CSP-02 Policy goals and mechanisms [2] ITE-CSP-03 Security services, mechanisms, and countermeasures [4] ITE-CSP-04 Cyber attacks and detection [4] ITE-CSP-05 High assurance systems [4] ITE-CSP-06 Vulnerabilities, threats, and risk [5] ITE-CSP-07 Anonymity systems [2] ITE-CSP-08 Usable security [3] ITE-CSP-09 Cryptography overview [3] ITE-CSP-10 Malware fundamentals [2] ITE-CSP-11 Mitigation and recovery [3] ITE-CSP-12 Personal information [2] ITE-CSP-13 Operational issues [4] ITE-CSP-14 Reporting requirements [1]	**ITE-GPP Global Professional Practice** [25 hours] ITE-GPP-01 History and overview [1] ITE-GPP-02 Professional issues and responsibilities [2] ITE-GPP-03 IT governance and resource management [2] ITE-GPP-04 Risk identification and evaluation [2] ITE-GPP-05 Environmental issues [2] ITE-GPP-06 Ethical, legal, and privacy issues [2] ITE-GPP-07 Intellectual property [3] ITE-GPP-08 Project management principles [3] ITE-GPP-09 Communications [3] ITE-GPP-10 Teamwork and conflict management [2] ITE-GPP-11 Employability skills and careers in IT [2] ITE-GPP-12 Information systems principles [1]
ITE-UXD User Experience Design [20 hours] ITE-UXD-01 History and overview [1] ITE-UXD-02 Human factors in design [4] ITE-UXD-03 Effective interfaces [5] ITE-UXD-04 Application domain aspects [2] ITE-UXD-05 Affective user experiences [2] ITE-UXD-06 Human-centered evaluation [3] ITE-UXD-07 Assistive technologies and accessibility [2] ITE-UXD-08 User advocacy [1]	

Table 5.1b: Supplemental IT Domains
(130 Hours selected from 245 possible hours)

Proposed Supplemental IT Domains and Hours	
ITS-DSA Data Scalability and Analytics [30 hours] ITS-DSA-01 History and overview [1] ITS-DSA-02 Foundations [8] ITS-DSA-03 Data Management [4] ITS-DSA-04 Methods, techniques, and tools [6] ITS-DSA-05 Data governance [5] ITS-DSA-06 Applications [6]	**ITS-ANE Applied Networks** [30 hours] ITS-ANE-01 Proprietary networks [6] ITS-ANE-02 Network programming [5] ITS-ANE-03 Routing protocols [4] ITS-ANE-04 Mobile networks [4] ITS-ANE-05 Wireless networks [4] ITS-ANE-06 Storage area networks [2] ITS-ANE-07 Applications for networks [5]
ITS-IOT Internet of Things [30 hours] ITS-IOT-01 History and overview [1] ITS-IOT-02 IoT architectures [4] ITS-IOT-03 Sensor and actuator interfacing [2] ITS-IOT-04 Data acquisition [3] ITS-IOT-05 Wireless sensor networks [4] ITS-IOT-06 Ad-hoc networks [2] ITS-IOT-07 Automatic control [4] ITS-IOT-08 Intelligent information processing [4] ITS-IOT-09 IoT application and design [6]	**ITS-MAP Mobile Applications** [25 hours] ITS-MAP-01 History and overview [1] ITS-MAP-02 Architectures [2] ITS-MAP-03 Multiplatform mobile application development [5] ITS-MAP-04 Servers and notifications [2] ITS-MAP-05 Performance issues [3] ITS-MAP-06 Views and gestures [3] ITS-MAP-07 Interface implementations [4] ITS-MAP-08 Camera, state, and documents interaction [3] ITS-MAP-09 2D graphic and animation [2]
ITS-SDM Software Development and Management [20 hours] ITS-SDM-01 Process models and activities [5] ITS-SDM-02 Platform-based development [2] ITS-SDM-03 Tools and services [4] ITS-SDM-04 Management [5] ITS-SDM-05 Deployment, operations, maintenance [4]	**ITS-SRE Social Responsibility** [20 hours] ITS-SRE-01 Social context of computing [4] ITS-SRE-02 Goals, plans, tasks, deadlines, and risks [4] ITS-SRE-03 Government role and regulations [3] ITS-SRE-04 Global challenges and approaches [3] ITS-SRE-05 Risk management [3] ITS-SRE-06 Energy standards and utilities [3]
ITS-VSS Virtual Systems and Services [30 hours] ITS-VSS-01 History and overview [1] ITS-VSS-02 Application of virtualization [5] ITS-VSS-03 User platform virtualization [3] ITS-VSS-04 Server virtualization [3] ITS-VSS-05 Network virtualization [5] ITS-VSS-06 Cluster design and administration [5] ITS-VSS-07 Software cluster applications [5] ITS-VSS-08 Storage [3]	**ITS-CCO Cloud Computing** [30 hours] ITS-CCO-01 History and overview [1] ITS-CCO-02 Concepts and fundamentals [6] ITS-CCO-03 Security and data considerations [6] ITS-CCO-04 Using cloud computing applications [5] ITS-CCO-05 Architecture [4] ITS-CCO-06 Development in the cloud [4] ITS-CCO-07 Serves and platforms [4]
ITS-CEC Cybersecurity Emerging Challenges [30 hours] ITS-CEC-01 Case studies and lessons learned [2] ITS-CEC-02 Network forensics [4] ITS-CEC-03 Stored data forensics [4] ITS-CEC-04 Mobile forensics [2] ITS-CEC-05 Cloud security [2] ITS-CEC-06 Security metrics [2] ITS-CEC-07 Malware analysis [3] ITS-CEC-08 Supply chain and software assurance [2] ITS-CEC-09 Personnel and human security [2] ITS-CEC-10 Social dimensions [2] ITS-CEC-11 Security implementations [2] ITS-CEC-12 Cyber-physical systems and the IoT [3]	

Table 5.2 shows the IT domains as presented in this report together with their essential or supplemental classifications. Note that some domains cross both essential and supplemental classifications. The table also shows the learning hours associated with each domain. The IT2017 task group has chosen to approximate these hours to the nearest "five" value to provide another dimension of flexibility to evolving information technology programs. See section 5.2 regarding the IT2017 total essential hours and the total supplemental hours.

Table 5.2: IT Curricular Framework and Relative Hours

IT Domains	Essential Hours	Supplemental Hours
Essential Only		
User Experience Design	20	0
Information Management	40	0
System Administration and Maintenance	20	0
Platform Technologies	15	0
System Integration and Architecture	20	0
Integrated Systems Technology	20	0
Subtotal:	**135**	**0**
Essential + Supplemental		
Software Fundamentals / Software Development and Management	30	20
Networking / Applied Networks	35	30
Web and Mobile Systems / Mobile Applications	25	25
Cybersecurity Principles / Cybersecurity Emerging Challenges	40	30
Global Professional Practice / Social Responsibility	25	20
Subtotal:	**155**	**125**
Supplemental Only		
Cloud Computing	0	30
Data Scalability and Analytics	0	30
Virtual Systems and Services	0	30
Internet of Things	0	30
Subtotal:	**0**	**120**
IT2017 TOTAL:	**290**	**130 / 245***

* = Supplemental domains should be at least 130 hours out of 245 hours

5.2.1 Related Mathematics

The IT2017 task group recommends that a robust information technology program should have at least discrete structures (mathematics) and other mathematical experiences that accumulate to at least 90 learning hours in supplemental mathematics to produce a competent IT professional for the mid-2020s. Institutions offering programs in information technology must ensure that students entering the program have the necessary mathematical prerequisites to engage in university-level mathematics courses. Prerequisites vary by region but they should include pre-calculus knowledge comprising arithmetic, basic algebra, and functions.

In a manner similar to the IT domains, we partition the mathematics portion of the IT curricular framework into essential and supplemental domains. The essential mathematics domain consists of 30 hours of discrete structures. Table 5.3 depicts this single domain with its accompanying subdomains and hours. The supplemental domain consists of 60 hours selected from college-level mathematics appropriate for the IT discipline. These include but not limited to the following.

- Probability
- Statistics
- Financial modeling
- Linear algebra, and
- Calculus

Programs should seek to include as much mathematics as possible that reflects its goals, the needs of its constituents, and that which is appropriate so their graduates can achieve success in industry or in graduate studies.

Table 5.3: Related IT Essential Mathematics
(30 Essential Hours)

Proposed IT Essential Mathematics Domain	
ITM-DSC Discrete Structures [30 hours]	
ITM-DSC-01	History and overview [1]
ITM-DSC-02	Sets [2]
ITM-DSC-03	Functions and relations [3]
ITM-DSC-04	Proof techniques [3]
ITM-DSC-05	Logic [2]
ITM-DSC-06	Boolean algebra principles [2]
ITM-DSC-07	Minimization [3]
ITM-DSC-08	Graphs and trees [4]
ITM-DSC-09	Combinatorics [3]
ITM-DSC-10	Iteration and recursion [2]
ITM-DSC-11	Complexity Analysis [2]
ITM-DSC-12	Discrete information technology applications [3]

5.2.2 Related Science

The IT2017 task group has elected not to recommend specific science domains or the number of hours that a program should devote to science. However, it does recommend that students undertaking an information technology program engage in as much science as appropriate to the goals of the program. Both industry and faculty surveys favor physics for such a selection. The reason for a science recommendation is that students in the technological field should develop strong analytical thinking skills and learn empirical and experimental ways of learning.

5.3 IT Domains

Each IT domain is briefly described by a set of scope statements that express the domain's curricular content. The following is the scope for each IT domain in the IT2017 curricular framework.

5.3.1 Essential IT Domains

The following summaries reflect the scopes of all essential domains as they appear in Appendix A. The totality of all these scope statements represent the essential component of information technology.

ITE-NET Networking
1. Topology of ad hoc and fixed networks of all sizes
2. Role of the layered model in standards evolution and interoperability
3. Physical layer through routing layer issues
4. Higher layers related to applications and security
5. Approaches to designing for and modeling latency, throughput, and error rate

ITE-WMS Web and Mobile Systems
1. Web-based applications including related software, databases, interfaces, and digital media
2. Mobile applications including related software, databases, interfaces, and digital media
3. Contemporary web technologies, semantic web, social media

ITE-IMA Information Management
1. Tools and techniques for efficient data modeling, collection, organization, retrieval and management
2. Tools and techniques for extracting information from data to make it meaningful to an organization
3. Development, deployment of data and information systems to support an organization
4. Safety and security issues associated with data and information

ITE-SWF Software Fundamentals

1. Skills and concepts essential to good programming practice and problem solving
2. Fundamental programming concepts, basic data structures, and algorithmic processes
3. Event-driven programming, object-oriented programming

ITE-SIA System Integration and Architecture

1. Skills and tools to gather requirements, source code development, evaluation and integration of components into a single system, and system validation
2. Fundamentals of project management and the interplay between IT applications and related organizational processes
3. System integration issues, including integration in a system of systems and federation of systems, role of architectures in systems integration, performance and effectiveness

ITE-SAM System Administration and Maintenance

1. Design, selection, application, deployment, and management of computing systems to support an organization
2. Skills and concepts essential to the administration of operating systems, networks, software, file systems, file servers, web systems, database systems, and system documentation, policies, and procedures
3. Education and support of users of computing systems

ITE-PFT Platform Technologies

1. Comparison of various operating systems available, including their respective characteristics, advantages and disadvantages
2. Selection, deployment, integration and administration of platforms or components to support the organization’s IT infrastructure
3. Fundamentals of hardware and software and how they integrate to form the essential components of IT systems

ITE-IST Integrated Systems Technology

1. Scripting languages, their uses and architectures
2. Application programming interfaces
3. Programming practices to facilitate the management, integration and security of the systems that support an organization

ITE-CSP Cybersecurity Principles

1. Identification of policies, mechanisms, services, and countermeasures related to cybersecurity
2. Cyber-attacks, cyber-detection, services and operational issues, security mechanisms and detection
3. Vulnerabilities, threats, risks, concealment, cyphers and deciphers, encryption, and decryption
4. Malware operations, mitigation, and recovery
5. Data and information security, security breaches, and reporting requirements

ITE-GPP Global Professional Practice

1. Historical, social, professional, ethical, and legal aspects of computing
2. Importance of identifying and understanding essential skills required for a successful career within the industry
3. Identification of ways teamwork integrates throughout IT and ways IT supports an organization
4. Social and professional contexts of information technology and computing, and adherence to ethical codes of conduct
5. Importance of business professional oral and written communication skills

ITE-UXD User Experience Design

1. Understanding of advocacy for the user in the development of IT applications and systems
2. Development of a mind-set that recognizes the importance of users, context of use, and organizational contexts
3. Employment of user-centered methodologies in the design, development, evaluation, and deployment of IT applications and systems

4. User and task analysis, human factors, ergonomics, accessibility standards, experience design, and cognitive psychology

5.3.2 Supplemental IT Domains

The following summaries reflect the scopes of all supplemental domains as they appear in Appendix A. These scope statements represent additional or applied components of information technology. Programs following these guidelines are encouraged to choose those domains that best reflect the program's purposes and objectives.

ITS-DSA Data Scalability and Analytics

1. Key technologies for collecting, cleaning, manipulating, storing, analyzing visualizing, and extracting useful information from large and diverse data sets
2. Instructional algorithms for analyzing large sets of structured and unstructured data
3. Challenges of large scale data analytics in different application domains

ITS-ANE Applied Networks

1. Purpose and role of proprietary network protocols, and comparing proprietary networks with open standard protocols
2. Protocols and languages in network programming; socket-based network application programs design and implementations
3. Components of Voice over IP (VoIP) networks and protocols, and configurations of voice gateways for supporting calls using various signaling protocols
4. Scientific field routing and protocols in the internet, IPv6 and the internet protocol of the future
5. Basic mobile network architectures and protocols used in wireless communications

ITS-IOT Internet of Things

1. Core knowledge and skills required to engage in the creative development and design of innovative IoT solutions
2. Trends and characteristics in IoT
3. Analysis of the challenges and applying adequate patterns for user-interaction in IoT
4. Impact of IoT in signal processing, data acquisition and wireless sensor networks
5. Relationships between IoT and intelligent information processing
6. General internet operations compared with internet of things operations

ITS-MAP Mobile Applications

1. Mobile application technologies with experiences to create mobile applications
2. Mobile architectures, including iOS and Android
3. Creation of mobile applications on different platforms
4. Evaluation and performance improvement of mobile applications

ITS-SDM Software Development and Management

1. Software process models and software project management
2. Software development phases: requirements and analysis, design and construction, testing, deployment, operations, and maintenance
3. Modern software development and management platforms, tools, and services

ITS-SRE Social Responsibility

1. Historical, social, governmental and environmental context of computing
2. Importance of team dynamics to an organizations' success
3. Governmental regulations address global challenges
4. Professional contexts of information technology and the role of risk management
5. Energy standards and regulations

ITS-VSS Virtual Systems and Services

1. Virtualization and its related open source components
2. Deployment skills to build virtualization and clustered solutions
3. Networked storage for virtualization infrastructure needs

ITS-CCO Cloud Computing

1. Concepts of cloud computing as a new computing paradigm
2. Cloud computing fundamentals, security principles and applications
3. Theoretical, technical and commercial aspects of cloud computing
4. Architecture and cloud software development
5. Case studies and existing cloud-based infrastructure

ITS-CEC Cybersecurity Emerging Challenges

1. Forensics as related to networks, data storage and mobile devices
2. Security techniques and metrics associated with hardware and software elements
3. Skills needed for administering, securing, and implementing information systems and networks
4. Emerging areas that increase risk

5.4 Rationale for 420 Hours in Information Technology

Within a typical academic context, a four-year undergraduate program has at least 120 credits (or semester hours), whereby one year of study consists of two semesters or 30 credits; one semester consists of 15 credits. We define one credit (or one semester hour) as the equivalent of one learning hour (one 50-minute time unit) per week for 15 weeks. Hence, thirty semester hours (one year of study) is equivalent to 30*15 = 450 learning hours.

It is common to include examination time within the fifteen weeks of a semester. However, if we exclude examination time, which might be the equivalent of one week during a fifteen-week semester, then one semester hour (credit) is equivalent to fourteen learning hours plus one examination hour. Hence, one year of study excluding examinations is equivalent to 30*14 = 420 learning hours, or simply 420 hours.

The IT2017 task group believes a student in information technology should experience at least the equivalent of 6 semester hours (or credits) in mathematics, which is 20% of 30 semester hours (credits). Hence, since 30 semester hours (one year) equals 450 learning hours, then 20% of 450 = 90 learning hours or simply 90 hours.

Table 5.5 provides a summary of some calculations that occur for the IT2017 curricular framework. The summary may prove useful for curriculum planning and development.

Table 5.5: Summary Calculations

Number of IT learning hours (total):	420 hours
Number of IT learning hours (Essential):	290 hours
Number of IT learning hours (Supplemental):	130 hours
Number of essential IT domains:	11
Number of supplemental IT domains:	4 Minimum (depends on supplemental IT domain selection)
Number of total IT domains:	15 Minimum (depends on supplemental IT domain selection)
Number of essential math domains:	1
Number of supplemental math domains:	Not yet specified
Average number of learning hours per IT domain:	28 = 420/15 (depends on supplemental IT domain selection)

The aforementioned discussion provides a minimal framework for implementing the curriculum for an information technology program. Strong IT programs would have much more mathematics and IT domain content to produce competent and competitive graduates for IT industries or for graduate studies. Such programs could have double the minimal number of hours for a durable IT program.

Chapter 6: Implementing the IT Curricular Framework

The previous chapter outlined the structure and content of the IT curricular framework. To implement the framework, IT programs must also ensure that students have the background knowledge and soft skills exposure they need to succeed in a career as well as the chance to specialize in IT domains that go beyond the boundaries of the core. This chapter offers strategies and guidelines on these issues. Section 6.1 addresses general requirements that support the broad education of IT students, including the non-technical skills described in Chapter 3 that are so important to success in the industry. Section 6.2 gives some advice on how programs can tailor the IT curricular framework presented here with specializations to meet local needs. It also briefly reviews IT programs in several countries. Section 6.3 shows how should IT professionals relate to an era of emerging technologies. .

6.1 General Requirements

A successful IT graduate needs many skills beyond the technical IT and mathematics skills found in the IT curricular framework. IT students must have effective communication and teamwork skills, familiarity with the methods of science, a sense of how computing is applied in practice, and preparation for being a well-rounded and effective member of society. This section outlines several general recommendations for IT programs seeking to meet these goals.

6.1.1 Communication Skills

As stated in Chapter 3, a widely-heard theme among employers is that IT professionals must be able to communicate effectively with colleagues and clients. Because of the importance of good communication skills in all computing careers, IT students must sharpen their oral and writing skills in a variety of contexts -- both inside and outside of IT courses. In particular, students in IT programs should be able to:

- Communicate ideas effectively in written form
- Make effective oral presentations, both formally and informally
- Understand and offer constructive critiques of the presentations of others
- Have a pleasant demeanor as they work with people on their IT needs, either in person or by phone
- Write appropriate electronic communications (including email, blogs, instant messages, etc.) to all levels of workers in all IT endeavors.

While institutions may adopt different strategies to accomplish these goals, the program for each IT student must include numerous occasions for improving writing and practicing oral communication in a way that emphasizes both speaking and active listening skills.

At a minimum, an IT curriculum should require:

- Course work that emphasizes the mechanics and process of writing
- At least two formal oral presentations to a group
- The opportunity to critique at least two oral presentations

Furthermore, the IT curriculum should integrate writing and verbal discussion consistently in substantive ways. Communication skills should not be seen as separate but should instead be fully incorporated into the IT curriculum and its requirements.

6.1.2 Teamwork Skills

As mentioned in Chapter 3, computing professionals cannot expect to work in isolation for very much of the time. Information technology projects are usually implemented by diverse groups of people working together as a team. Information technology students therefore need to learn about the mechanics and dynamics of effective team participation as part of their four-year education. An IT program should provide opportunities to utilize communication, negotiation, and collaborations skills in a team setting to achieve a common goal. Because the value of working in teams, as well as the difficulties that arise, do not become evident in small-scale projects, students need to engage in team-oriented projects that extend over a reasonably long period of time, such as a full semester or a significant fraction thereof. Moreover, IT students should experience working in teams with non-IT students whenever possible.

To ensure that students have the opportunity to acquire these skills as undergraduates, we recommend that all IT programs include the following:

- Opportunities to work in teams beginning relatively early in the curriculum.
- A significant project that involves a complex implementation task in which both the design and implementation are undertaken by a small student team.
- Project are often scheduled for the last year of undergraduate study, where it can serve as a capstone for the undergraduate experience.

The experience that students derive from a significant team project can be enhanced further by using teams that cross disciplinary boundaries. As an example, IT students can work with students from engineering, artistic design, or marketing to conduct a project requiring expertise from multiple disciplines. We strongly endorse the concept of diverse interdisciplinary team projects, and note that such projects provide a rich and valuable experience for students, both inside and outside of information technology.

6.1.3 Scientific Methods

The process of abstraction (data collection, hypothesis formation and testing, experimentation, analysis) represents a vital component of logical thought within the field of computing. The scientific method represents a basic methodology for much of the realm of computing, so students should have a solid exposure to this methodology.

To develop a firm understanding of the scientific method, students must have direct hands-on experience with hypothesis formulation, experimental design, hypothesis testing, and data analysis. While a curriculum may provide this experience in various ways, it is vital that students must "do science" -- not just "read about science."

We therefore make the following recommendations about science:

- Students must develop an understanding of the scientific method and experience this mode of inquiry in courses that provide some exposure to laboratory work.
- Students may acquire their scientific perspective in a variety of domains, depending on program outcomes and their area of interest.

6.1.4 Engaging in Related Areas

Due to the pervasiveness of information technology throughout nearly every field of human endeavor, IT students must be able to work effectively with people from other disciplines, and apply IT to other disciplines. To this end, we recommend that all information technology students engage in an in-depth study of some subject that uses computing in a substantive way.

IT students have a wide range of interests and professional goals. Study of computing together with an application area will be extremely useful and could be accomplished in several ways. One approach is to integrate case studies into IT courses in a way that emphasizes the importance of understanding the application domain. Other approaches might include an extended internship experience or the equivalent of a full semester's work that would count toward a major in that discipline. Additionally, IT students should be encouraged to consider a minor in another discipline. Such opportunities exist in such fields as health, economics, statistics, data science, business, the sciences, and many other disciplines.

6.1.5 Becoming a Contributing Member of Society

Regardless of the depth or focus of one's technical background, each person is expected to operate effectively and amicably in society. This includes accepting and valuing the diverse opinions and perspectives of others, awareness that their professional knowledge provides them with unique opportunities to contribute to society, and understanding the implications of social and political developments. IT students should be able to discuss significant trends and emerging technologies and their impact on our global society.

6.2 IT Curricular Framework and IT Programs

6.2.1 Tailoring the Curriculum

The IT curricular framework presented in this report consists of essential and supplemental IT domains, as discussed in Chapter 5. An IT program curriculum is expected to include all the essential IT domains and a selection of the supplemental IT domains. This structure allows tailoring the area of specialization for a degree program. Added to the foundation of the essential competencies, the 270 supplemental hours may be chosen from among supplemental IT domains to construct a curriculum that meets the needs of a local business community.

In implementing the IT curricular framework, we encourage thoughtful construction of the curriculum to create a program that meets local needs and/or produces graduates with a market-worthy specialization. As a counterexample, choosing the most introductory competencies from every supplemental IT domain to meet the recommended supplemental hours could produce a graduate with too much breadth and not enough depth to have useful skills in today's job market.

6.2.2 IT Curricula and Global Diversity

The structure and format of IT programs vary significantly from institution to institution and from country to country. In the following paragraphs, we briefly review IT programs in several countries including China, European countries, Japan, India, Philippines, Saudi Arabia, and the United States.

In China, IT programs have gone beyond the traditional major of computer science and technology (CST) and software engineering (SE). Currently, China elaborates on eight IT degree programs that the Chinese education ministry recently updated or newly designed. There are four sub-disciplines within the discipline of *computing*; network engineering, information security, internet of things engineering, and digital media techniques. In addition, there are four *interdisciplinary* programs related to information technology, which are health informatics, bioinformatics, geographic information science, and information systems management.

In Europe the situation varies.

- In Scotland, there are two different kinds of undergraduate IT degree offerings. The first are degree programs that combine computing courses with management courses. Examples of these include the IT management for business degree at Glasgow Caledonian University [Gcu1] and the information technology management degree at Edinburgh Napier University [Nap1]. The other type of information technology degree is one that combines many aspects of computing technology for example the information technology degree at the University of the West of Scotland [Uws1] that combines computing science courses, music technology courses, computer animation courses, and business technology courses. Programming competence is not a requirement to graduate from many IT programs. Hence, such IT degrees are quite distinct with computing or informatics degrees.

- In the United Kingdom, the British Computer Society (BCS) offers accreditation for computing degrees offered. An IT degree could be accredited to the Chartered IT Professional level if at least 50% of the courses are in computing. The set of the full criteria appears at the BCS website [Bcs1]. Please note that accreditation is optional and that a number of the universities in Scotland have opted out of this system. Such accreditation is seen as diminishing the quality of degrees by certain universities. There are also one-year IT master degree programs in IT. These are often conversion degrees, meaning that they allow students with any undergraduate degree subject to enter and be ‘converted’ into IT professionals.

- In France, information technology programs have been recently influenced by the ACM computer science curricula (CS2013) and the IEEE software engineering body of knowledge (SWEBOK). Content from other disciplines such as physics, mathematics and chemistry have decreased to leave more space to information technologies. Most of the undergraduate programs contains two full years (year-2 and year-3) dedicated to IT while the first year still has broader views on sciences and is used as a common portal for teaching programs in multiple scientific domains. Usually, various sub-programs target different careers in IT using specialization such as developer for new technologies, network engineering, as well as internet and media communication. Note that most students will continue with a two-year education in a computing sciences master’s degree.

- In Finland, various bachelor degrees in computer science, information system science, and in general, in information and communication technologies (ICT) can be obtained from universities and from polytechnics (universities of applied sciences). For new students, most of the universities’ master’s programs begin with bachelor studies (three years). The total number of different degree programs in ICT in the country is well above fifty, with varying focus areas (e.g., cyber security, web intelligence, service engineering, music technology, business information systems, bioinformatics, geoinformatics, big data, and human-technology interaction). People's interest towards IT in general and ICT education in particular has varied according to the various IT-hype created by Finnish media. Nokia's past success has been one of the main factors that have shaped Finns’ general attitudes. Since the beginning of the millennium the number of applicants in IT studies has been in slight decrease. Since 2010, however, there has been a surprising increase in the number of applicants (similar trend as in the United States). Potential explanations for the recent increase could be the recent success stories of Finnish gaming industry, and the realization that modern society is relying heavily on IT. Employment rate in the IT sector in Finland is high: within the first five years after graduation unemployment rate is between 3% to 5%, and after five years, unemployment rate almost zero percent. However, young women have a low interest towards IT education and careers. In addition, students at the university level typically show slow progress and low graduation rates. This is because more than 90% of the IT students work while studying and only about 50% of the students will eventually graduate. IT students typically work in the IT industry anyway, regardless of graduating or not. This problem cannot be solved easily because at the moment there is no regulation in IT sector of that will/can be employed (unlike teachers, lawyers and medical doctors). There is a "heroic" work tradition in the IT industry in Finland: diplomas and degrees don't weigh nearly as much as one's actual IT skills. There are no national IT curricula but some of the universities follow the international ACM, IEEE, or AIS curriculum guidelines in their IT curricula. In Finland, Aalto University, University of Jyväskylä, Technical University of Tampere, and University of Oulu provide the highest-level education and research profiles in IT according to the Ministry of Education and Culture [Jaa1].

- In Austria, information technology oriented education spans computer science, management, information systems, and a variety of specializations ranging from medical informatics, economy informatics to topics including human-computer interaction and human-centered computing. Education is offered at full universities and applied universities with more than twenty-five different bachelor programs, more than twenty-five different master programs distributed over more than ten different institutions and available for full-time students as well as part-time students. The majority of these programs focus on algorithms and programming structures, network engineering, information security, operating systems and the specification and realization of hardware/software/network systems. The broad variety of master’s programs allows students to specialized in topics ranging from geo-informatics to human-centered computing. In Austria the specialization for education starts at an early age. After nine years of obligatory school, a choice can be made between training in a company, a middle school, or a high-school (ending with 12 or 13 years of education with the so called ‘matura’). Education at universities and applied universities follows the Bologna structure with bachelor, master, and doctoral degrees.

- In Spain, the syllabus of informatics engineering (combining computer engineering, networks, software engineering, and computer science) and telecommunications engineering (including electronic engineering and computer networks with some subjects on software engineering). The syllabus also includes some compulsory disciplines (common to all the informatics studies in the country) on computer engineering (hardware design), network management, software engineering, as well as formal methods and artificial intelligence. Diverse optional disciplines provide different orientations, most frequently towards software engineering or computer science.

- In other European countries like the Netherlands and Poland, IT competency models on the undergraduate (bachelor) level have been published by the Ministry of Higher Education as a set of general learning outcomes. They cover a spectrum of knowledge, skills and social qualifications expected form each graduate in IT or computer science. Based on these outcomes, each IT faculty builds its own teaching program, reflecting specific profile of the university and expected profile of the graduate. These general outcomes cover a typical set of technical issues (e.g., networks, systems, architectures, databases, languages, AI, and security) supplemented by teamwork and communication management skills. Recently, in addition to user-centered design, many programs have an emphasis on adding novel skills essential to creative IT projects. These include interaction design, design thinking, agile project management methodologies, and managing efficient vendor-customer communication.

In Japan, in 2007, the Information Processing Society of Japan has released "Computing Curriculum Standard J07" that is based on Computing Curricula 2005 created by IEEE-CS and ACM. J07 provides five model curricula based on the five disciplines, which are computer engineering, computer science, information system, information technology and software engineering. Many major IT institutions provide programs based on these model curricula with some arrangement to meet needs of industries. Examples of such industrial needs are internet of things, game development, software as a service (SaaS), cloud based computing, and embedded system development. However, a strong regulation by the Ministry of Education, Culture, Sports, Science and Technology weakens flexibleness of such program designs.

In India, universities by and large have a four-year bachelor's programs in computer science and engineering, which covers a wide breadth of core courses addressing all foundational areas of computer science, and additional required courses and electives covering advanced topics. In addition, many universities have a four-year program in information technology, which has an emphasis on learning practical skills and less of theory, as well as a four-year program in computer engineering, which covers computer hardware in detail with basic coverage of software. In addition, many universities offer a three-year bachelor of science programs in computer science followed by a two-year master's program in computer science. Further, most universities offer a master of computer applications (MCA) program, which is a three-year graduate program that admits students with basic degrees in any of a variety of fields, and then offers courses similar to the information technology program, but with an even greater emphasis on practical technologies.

In the Philippines, IT programs are currently shifting to learning competency-based standards using outcome-based approach following the recommendation of the Commission on Higher Education. Based on the changes in primary and secondary education towards adopting the K-12 program, new and emerging developments in IT, and perceived needs in the IT industry in the Philippines, the document outlines three major IT programs for higher education institutions (HEI) in the Philippines to follow. These are the computer science program, which focuses on computing concepts, algorithms and software engineering; information technology program, which focuses on administering IT infrastructure; and information systems program, which focuses on managing IT for organizations. In general, all programs emphasize core concepts in software development, data structures & algorithm design, information management, applications development in web and mobile, user experience and design (human-computer interaction and design), and network/system administration and security. All programs outline the need for internships that immerse students in the IT industry. Lastly, there is also a growing push on sub-disciplines such as user-centric system design, agile movement, health informatics, natural language processing, and image processing.

In Saudi Arabia, information technology programs follow the guidelines as defined in the publication "Computing Curricula – Information Technology Volume" also known as IT2008. The framework of IT programs build around key strengths for robust programs in information technology. The focus on areas far beyond programming or immersive software development coupled with an intense exposure to mathematics and science generate strong critical thinking graduates. In addition, programs provide the potential to conduct projects, internships, and research together with an emphasis on training components to enhance the practical experience of students. IT programs also foster adaptability to change in job market needs by providing in-depth knowledge through specific concentrations that are easily interchangeable. Hence, respected IT programs in Saudi Arabia have enjoyed success with these principles and they serve as models for other IT programs in the region to emulate.

Information technology programs throughout the United States cover a convergence of computer science, management, and information systems. IT programs emphasize the integration and performance of information technology planning, development, implementation, and operation, together with the development of an infrastructure to support the processes necessary to achieve organizational objectives. In general, IT programs foster competencies in foundational areas that include software development, web and interactive media content and development, data management and database systems, and network system administration and security. Additionally, there is an emphasis on user-centric system definition, design and deployment, an area often considered a defining competency of IT professionals.

The IT2017 curricular framework complements the general characteristics described in the three mentioned countries. They also complement the technical and professional knowledge, skills, and attitudes needed to produce a competent graduate from an IT undergraduate program in the mid-2020s. Hence, implementation of a curriculum based on the IT curricular framework should serve well computing educational communities worldwide.

6.2.3 Interdisciplinary IT Programs

The manner in which institutions offer IT programs vary by local area, country, and geographic region. The previous section illustrated typical information technology programs offered in a quasi "pure" manner. That is, the IT programs are self-contained and independent of other programs administrative units of institutions might offer.

Because information technology is relatively new as a discipline, institutions sometimes offer IT baccalaureate degree programs within a previously established computing area. For example, an IT degree program could exist within an already established information systems program or within an established computer science program. In fact, because of institutional convenience, an institution might even offer all IT courses as simply subsets of an existing discipline.

Appendix C illustrates information technology programs offered within an interdisciplinary setting. …

[Completion of this section will appear in a future version of this report.]

6.3 Strategies for Emerging Technologies

The information technology field has changed rapidly in recent times and there is an unwritten promise that the change in these areas will accelerate drastically in the future. Hence, IT professionals must have the background to adapt to new and emerging technologies in an agile manner. They should be able to identify contributors to emerging technologies and identify companies that have failed because they did not adapt to a changing field.

So, how should IT professionals relate to an era of emerging technologies? One way is to identify stakeholders associated with some of these technologies and to identify some strategic assumptions and social values related to the development and application of these new areas. Often, industry breaks scientific barriers to formulate such strategies; sometimes governments set strategic polices to expand or confine these strategies. Standards might even emerge in dealing with emerging technologies. These strategies could involve supplemental technologies; others could be conceptual in nature.

6.3.1 Current Emerging Technologies

Information technology specialists should be aware of current emerging technologies. These technologies already exist in the marketplace but they are sufficiently new that their influence on society is not completely known. Students should be able to identify some of these emerging technologies and indicate their effects on IT.

The information technology curriculum should allow the exploration of emerging technologies. For example, teachers might encourage examination of ways in which 3D printers might produce artifacts that are harmful to society or describe the challenges one would face in designing cloud servers. As another example, students should be able to explain ways in which nanotechnology or the internet of things (IoT) can transform the technological workplace. Emergent and modern technologies present IT students and practitioners' challenges that could involve financial and ethical tradeoffs that affect professional practice in a changing world.

6.3.2 Conceptual Emerging Technologies

IT specialists should also be aware of conceptual emerging technologies. These technologies are those that exist in some developing state with recent entrance or possible entrance in the market place. Students should be able to identify some conceptual emerging technologies and indicate some of their effects of on information technology.

The IT curriculum should allow exploration of new inventions that have yet to emerge as viable technologies. For example, teachers might encourage exploration of ways in which an IT professional would design environments involving augmented reality and virtual worlds or ways in which big data and data analytics might affect the it field. Additionally, it would be useful to have students explore the role of an IT professional to discuss IT strategies needed in developing a culture of green computing and sustainability. New technologies might even expose safety issues affecting the IT field. Awareness of these and other issues are important in developing a well-rounded and social conscious information technologist.

Chapter 7: Institutional Adaptations

This chapter is designed primarily as a resource for colleges and universities seeking to develop or improve four-year programs in information technology. To this end, the appendices to this report offer an extensive analysis of the structure and scope of information technology competencies along with a detailed set of course descriptions that represent viable approaches to the four-year curriculum. Implementing a curriculum successfully, however, requires each institution to consider broad strategic and tactical issues that transcend such details. The purpose of this chapter is to enumerate some of these issues and illustrate how addressing those concerns affects curriculum design.

7.1 The Need for Local Adaptation

The task of designing an information technology curriculum is a difficult one in part because so much depends on the characteristics of the individual institution. Even if every institution could agree on a common set of knowledge and skills for undergraduate education, there would nonetheless be many additional factors that would influence curriculum design. These factors include the following:

- *The type of institution and the expectations for its degree programs.* Institutions vary enormously in the structure and scope of four-year degree requirements. The number of courses that institutions require of information technology majors can vary on the institution type.
- *The range of postgraduate options that students pursue.* Individual schools must ensure that the curriculum they offer gives students the necessary preparation for their eventual academic and career paths.
- *The preparation and background of entering students.* Students at different institutions, and often within a single institution, vary substantially in their level of preparation. As a result, information technology departments often need to tailor their introductory offerings so that they meet the needs of their students.
- *The faculty resources available to an institution.* There are limited information technology faculty members available to the institutions due to the limited number of graduate programs currently available in the information technology area. Therefore, departments need to set priorities for how they will use their limited faculty resources.
- *The interests and expertise of the faculty.* Individual curricula often vary according to the specific interests and knowledge base of the department, particularly at smaller institutions where expertise is concentrated in particular areas.
- *The specific needs of the local industry.* Individual curricula often customized to meet the needs of local businesses.

Creating a workable curriculum requires finding an appropriate balance among these factors, which will require different choices at every institution. There can be no single curriculum that works for all institutions. Every college and university will need to consider the various models proposed in this document and design an implementation that meets the need of that environment.

7.2 Principles for Curriculum Design

Despite the fact that curriculum design requires significant local adaptation, curriculum designers can draw on several key principles to help in the decision-making process. These principles include the following characteristics.

- *The curriculum must reflect the integrity and character of information technology as an independent discipline.* Information technology is a discipline in its own right. That discipline, moreover, is characterized by a combination of theory, practice, knowledge, and skills. Any information technology curriculum should therefore ensure that practice is guided both by theory and a spirit of professionalism.

- *The curriculum must respond to rapid technical change and encourage students to do the same.* Information technology is a vibrant and fast-changing field and therefore information technology programs must update their curricula on a regular basis. Of equal importance, the curriculum must teach students to respond to change as well. Information technology graduates must keep up to date with modern developments and should indeed be excited by the prospect of doing so. One of the most important goals of an information technology program should be to produce students who are life-long learners.

- *Curriculum design must be guided by the outcomes the program is intended to achieve.* Throughout the process of defining an information technology curriculum, it is essential to consider the goals of the program and the specific capabilities students must have at its conclusion. These goals and the associated techniques for determining whether the goals are met provide the foundation for the entire curriculum. In the United States and elsewhere, accreditation bodies have focused increasing attention on the definition of goals and assessment strategies. Programs that seek to defend their effectiveness must be able to demonstrate that their curricula in fact accomplish what they intend.

- *The curriculum as a whole should maintain a consistent ethos that promotes innovation, creativity, and professionalism.* Students respond best when they understand what is expected of them. It is unfair to students to encourage particular modes of behavior in early courses, only to discourage that same behavior in later courses. Throughout the entire curriculum, students should be encouraged to use their initiative and imagination to go beyond the minimal requirements. At the same time, students must be encouraged from the very beginning to maintain a professional and responsible attitude toward their work.

- *The curriculum should be accessible to a wide range of students.* All too often, information technology programs attract a homogeneous population that includes relatively few women or students whose ethic, social, or economic backgrounds are not those of the dominant culture. Although many of the factors that lead to this imbalance lie outside the control of the university, every institution should seek to ensure greater diversity, both by eliminating bias in the curriculum and by actively encouraging a broader group of students to take part.

- *The curriculum must provide students with a capstone experience that gives them a chance to apply their skills and knowledge to solve a challenging problem.* The culmination of a four-year information technology degree should include a final-year project that requires students to use a range of practices and techniques in solving a substantial problem. There are aspects of the information technology discipline that cannot be presented adequately in the formal classroom setting. These skills can be learned only in the framework of an independent capstone experience.

- *The faculty should constantly be looking for better ways to deliver the curriculum.* Constant improvement in all areas should be a hallmark of a healthy IT program.

7.3 Transitions into Four-year IT Programs

The traditional pathway into a four-year college degree program is entry after high school, with specific entry requirements varying by country, school, and program. This is not the path of all students though, and for many IT programs it is important to consider students who may enter the program with varying backgrounds and at points other than the beginning.

Educational pathways into and through IT programs are many. In a survey conducted of IT programs internationally [Sab1], 35% of respondents indicated that their program has few external transfers. Thirty-three percent indicated that two- or three-year schools are the primary source of transfer students into an IT program. A survey shows that smaller-represented sources of transfer were transfers due to life experiences (8%), and industry-university articulation transfers (3%), with 21% responding ‘not sure’ or ‘not available’. A significant finding from the survey was the overrepresentation of United States programs among those indicating two- or three-year schools as the primary transfer source: 69%, compared with United States institutions representing 35% of the pool.

Community colleges play a vital role in higher education in the United States. According to the American Association of Community Colleges, 46% of all undergraduate college students in the U.S. attend a community college (American Association of Community Colleges). Some of these students ultimately transfer into a four-year college degree program. Any IT program that accepts transfer students can help student success by creating a smooth path for articulation. This may involve partnering with two- or three-year programs or other entities involved in the IT educational pathway.

The ACM Committee for Computing Education in Community Colleges (CCECC) has published curricular guidance for associate degree (two-year) programs in the ACM-recoged computing disciplines. Among these is the Information Technology Competency Model of Competencies and Assessment for Associate-Degree Curriculum, published in 2014 [Haw1]. The IT2017 task group supports these guidelines and recommends programs consider them for students intending to transfer into IT programs. To aid in using the associate-degree guidelines in concert with IT2017, a mapping from one to the other will be constructed and made available on the ACM CCECC web site. At the time of this writing, a mapping to IT2008 is available [Acm2].

The aforementioned discussion applies mostly to institutions in the United States. However, normal transfers from a two-year institute to a four-year university is unlikely. In Japan, for example, a transition to a four-year university is not so common. Graduates of junior technical colleges can enroll in the third year of four-year institution through selection processes. However, a number of such students is less than 10% of entire student population. In general, a portion of non-traditional students is much higher in graduate schools compared to undergraduate institutes in Japan.

The only transition program available in India is master of computer applications programs, which allow students to join after a three-year bachelor's degree in any field. For all other programs, entry is right after normal education.

In Europe the situation varies. In Scotland, for example, it is normal for baccalaureate honors programs to be four years in duration. Direct entry to second year is sometimes available for well qualified individuals. In addition, before the process of European convergence on higher education, usually named the Bologna Process, there were five-year engineering degrees and they had a similar structure as found in all the Spanish universities. After the European convergence all these degrees were reduced to four years; one- or two-year master degrees were added for specialization. Currently, the syllabus of informatics engineering studies is different in each university with a common core accounting for one-third of the total credits. In other European countries (e.g., the Netherlands, Poland) there is only one type of undergraduate level: the bachelor of science degree consisting of six semesters (three years). In those cases, there is currently no four-year degree program in IT. Therefore, the diverse specialties and orientations offered by different universities make it unlikely to have normal transfers from two-year into universities is very unlikely.

7.4 The Need for Adequate Computing Resources

Higher education is, of course, always subject to resource limitations of various kinds. At some level, all educational programs must take costs into account and cannot do everything that they might wish to do if they were somehow freed from economic constraints. In many respects, those limitations are no more intense in information technology than they are in other academic fields. It is, for example, no longer the case that adequate computing and networking hardware lies outside the reach of academic institutions, as it did in the early days of the discipline. Over the last twenty years, computing and networking equipment have become commodity items, which makes the hardware far more affordable.

At the same time, it is essential for institutions to recognize that computing and networking costs are real. These costs, moreover, are by no means limited to the hardware. Software also represents a substantial fraction of the overall cost of computing and networking, particularly if one includes the development costs of courseware. Providing adequate support staff to maintain the computing and networking facilities represents another large expense. To be successful, information technology programs must receive adequate funding to support the computing and networking needs of both faculty and students.

Information technology is a laboratory discipline with formal, scheduled laboratories included in many courses. The laboratory component leads to an increased need for staff to assist in both the development of materials and the teaching of laboratory sections. This development will add to the academic support costs of a high-quality information technology program. Furthermore, as part of their academic initiatives, many vendors provide free labware for academia. For example, see IBM's internet of things with Bluemix (IoT Python app with a Raspberry Pi and Bluemix) [Ibm1] and Information Storage Management from EMC [Ndg1].

7.5 Attracting and Retaining Faculty Members

One of the most daunting problems that information technology departments face is the problem of attracting faculty members. To mitigate the effects of the faculty shortage, we recommend that institutions adopt the following strategies:

- *Adopt an aggressive plan for faculty recruitment.* Scarcity is in itself no reason to abandon the search; the shortage of candidates simply means that information technology departments need to look harder. Being successful is usually a matter of initiative and persistence. Departments must start the recruiting process very early and should consider reaching out to a wide range of potential applicants, including overseas students and people currently working in industry.
- *Create academic positions that focus on teaching.* As in most disciplines, faculty positions in information technology typically require a Ph.D. and involve expectations in both research and teaching. If there were a sufficient pool of IT candidates with the right credentials and skills, insisting on these qualifications would cause no problem. Given the present shortage of faculty candidates, it is not clear whether information technology departments can afford single-minded selectivity. It is not necessary for every institution to maintain a research program in information technology. At the same time, it is important for all faculty member to remain current in the field. Because IT is a new discipline, it would be wise to consider candidates from closely-related fields, such as information systems and computer science. Also, opening faculty positions to those who enjoy teaching but are not drawn to academic research can increase the size of the available pool.
- *Make sure that faculty receive the support they need to stay in academia.* Studies undertaken by the National Science Foundation in the 1980s found that faculty members who left academia for industry typically did not cite economics as their primary motivation [Cur1]. Instead, they identified a range of concerns about the academic work environment, huge class sizes, heavy teaching loads, inadequate research support, the uncertainty of tenure, and bureaucratic hassles, that the NSF study refers to collectively as "institutional disincentives." As enrollments in information technology courses rise, it is critical for institutions to ensure that faculty workloads remain manageable.
- *Get undergraduates involved as course assistants.* Given that there are too few teachers to serve the needs of the many undergraduates, one of the best ways to meet the rising student demand is to get those undergraduates involved in the teaching process. Using undergraduates as course assistants not only helps alleviate the teaching shortfall but also provides a valuable educational experience to the student assistants [Rob1].

7.6 Faculty Commitment to the Degree Program

IT programs can make effective use of faculty from a variety of computing disciplines. However, it is essential that there be a core group of dedicated faculty who can provide the right perspective and knowledge to make the program work overall. Specifically, this core group must provide:

- *Experience* – Since IT is a practice-oriented discipline, it is important that many of the faculty have hands-on, practical experience in the core information technologies.
- *Commitment to change* – The rapid evolution of computing requires regular update of all computing programs. For IT, there is a particular need to continue to mirror practice, including continually updating specific technology examples used in labs and demos.
- *Commitment to coordination* – The pervasive themes discussed earlier in this document are central elements in the overall IT degree. However, it is challenging to make sure that these themes are integrated in the curriculum without program-level coordination among instructors. This level of cross-course coordination is difficult to achieve and maintain in most institutions of higher education. Without conscious, continual effort by the faculty to communicate and coordinate, integration of pervasive themes will be uneven at best.

7.7 Information Technology Across Campus

The IT general-education and service courses can be used to give students information about IT career options they might not have considered before and help IT programs to attract more students into the discipline. The following are those distinct types of competencies for inclusion in a general-education course in information technology.

- *Information technology-specific skills:* This class of knowledge refers to the ability to use contemporary information technology applications such as information management, networking, information assurance, human-computer interaction, and web systems and technologies.
- *Fundamental and enduring information technology concepts:* Concepts explain the how and why of information technology and they give insight into its opportunities and limitations. They include persuasive themes in IT, history of information technology, application domains, organizational issues, data modeling, data organization and retrieving, integrative programming, emerging technologies, and system integration and architecture.
- *General intellectual capabilities:* This class of competencies consists of broad intellectual skills important in virtually every area of study, not simply information technology. These skills allow students to apply information technology to complex tasks in effective and useful ways. Examples include problem solving, managing complexity through abstraction, modeling, use of appropriate tools, inter-personal skills, project management, developing effective interfaces, assets management and cost/benefit analysis, logical reasoning, ethics, and effective oral and written communication skills. These capabilities are beneficial to all students and help to develop and improve a student's overall intellectual ability.

IT general-education and service courses should cover core IT concepts including emerging technologies, teach students how to find appropriate computing technologies to complete a task, be familiar with ethical, legal, and social issues related to information technology and essential issues related to cybersecurity and privacy. These courses should be flexible to accommodate different application domains for different fields of study.

The integrative nature of information technology discipline helps create interdisciplinary courses. The applied IT courses should demonstrate application of computing systems within the context of a specific subject or field of study. In these courses students from non-computing disciplines will learn the information technology terminology and will be ready to interpret and communicate information accurately in enterprise settings. These courses will help to produce better professionals by equipping them with IT skills. For example, a data driven journalism course might include information technology curricular content and practices such as the basics of data acquisition, cleaning, analysis, key programming, and web development concepts.

The information technology minor should attract students for whom a deeper understanding of information technology would provide an additional benefit beyond courses in their major. For many disciplines, practical application of information technology is essential to their career success. For example, the job ads for marketing professionals list many computing skills including customer relationship management (CRM) software, search engine optimization (SEO) technics, web analytics and SQL. Moreover, employers require that electrical engineers have the ability to program and write UNIX shell scripts. Having an IT minor will better prepare students for careers in their field.

Due to the ever-changing nature of the information technology field, the industry is looking for individuals with advanced skills and knowledge in existing or emerging IT domains (e.g. information security and health IT). IT departments might consider offering standalone academic certificates in information technology or a specific area of IT.

7.8 Conclusion

There is no single formula for success in designing an information technology curriculum. Although the task group believes that the recommendations of this report and the specific strategic suggestions in this chapter will prove useful to a wide variety of institutions, every information technology program must adapt those recommendations and strategies to match the characteristics of the particular institution.

Students of information technology should consider taking market-specific courses toward the end of their studies to prepare themselves for the skills that are current and in demand in the marketplace. It is, moreover, important to evaluate and modify curricular programs on a regular basis to keep up with the rapid changes in the field. The information technology curricula in place today are the product of many years of experimentation and refinement by information technology educators in their own institutions. The curricula of the future will depend just as much on the creativity that follows in the wake of this report to build even better information technology programs for undergraduates throughout the world.

Appendix A:
Information Technology Curricular Framework

A.1 Essential IT Domains

ITE-NET Networking
[35 hours]

Domain Scope
1. Topology of ad hoc and fixed networks of all sizes
2. Role of the layered model in standards evolution and interoperability
3. Physical layer through routing layer issues
4. Higher layers related to applications and security, such as functions and design
5. Approaches to designing for and modeling latency, throughput, and error rate

<u>ITE-NET Subdomains</u>

ITE-NET-01 History and overview
Minimum instructional hours: 1 hour

Competencies:
a. Define networking and describe the research scope of networking study.
b. Identify some components of a network.
c. Name two network devices and describe their purpose.
d. Describe ways information technology uses or benefits from networks.
e. Illustrate the role of networks in information technology.
f. Identify people who influenced or contributed to the area of networks.
g. Identify two contributors to networks and relate their achievements to the area.

ITE-NET-02 Foundations of networking
Minimum instructional hours: 3 hours

Competencies:
a. Identify two current standards (e.g., RFC's and IEEE 802) and explain how standards bodies and the standardization process impact networking technology.
b. Contrast the OSI and internet models as they apply to contemporary communication protocols.
c. Explain why different technologies are deployed in different contexts of networking, such as topology, bandwidth, distance, and number of users.
d. Explain the basic components and media of network systems and distinguish between LANs and WANs.
e. Explain how bandwidth and latency impact throughput in a data communications channel.
f. Deploy a basic Ethernet LAN and compare it to other network topologies.
g. Explain the concept and allocation of addressing scheme which involves port numbers, IPv4 and IPv6 address.
h. Configure a client and a server operating system and connect the client machine to the server over a LAN.
i. Analyze and compare the characteristics of various communication protocols and how they support application requirements.
j. Demonstrate the ability to solve basic problems and perform basic troubleshooting operations on LANs and connected devices.

ITE-NET-03 Physical layer
Minimum instructional hours: 3 hours

Competencies:
a. Explain how the three variables of Shannon's law impact channel capacity.
b. Compare the bandwidth characteristics of several types of physical communication media.
c. Contrast the historical evolution of the switched and routed infrastructures.
d. Analyze the physical challenges inherent in wireless-fixed and wireless-mobile communication channels.
e. Compare methods of error detection and correction such as parity, cyclic redundancy check (CRC), and error detection and correction (EDC).

f. Describe the development of modern communication standards, addressing both de jure and de facto standards.
g. Choose the appropriate compression methodology (lossy or lossless) for a given type of application.
h. Analyze and compare four networking topologies in terms of robustness, expandability, and throughput.

ITE-NET-04 Networking and interconnectivity
Minimum instructional hours: 7 hours

Competencies:

a. Describe the seven layers of the OSI model.
b. Contrast the differences between circuit switching and packet switching.
c. Contrast point-to-point network line configuration with multipoint configuration.
d. Explain some networking and internetworking devices such as repeaters, bridges, switches, routers, and gateways.
e. Explain network topologies such as mesh, star, tree, bus, ring, 3-D torus.
f. Contrast connection-oriented services with connectionless services.
g. Explain network protocol features such as syntax, semantics, and timing.
h. Explain layered protocol software (stacks) such as physical-layer networking concepts, data-link layer concepts, internetworking, and routing.
i. Contrast protocol suites such as IPv4, IPv6, IPvN, and TCP/UDP.
j. Explain the operation principles of some main protocols, such as FTP and SNMP.
k. Identify network standards and standardization bodies.

ITE-NET-05 Routing and switching
Minimum instructional hours: 7 hours

Competencies:

a. Describe data communications and telecommunications models, digital signal processing, topologies, protocols, standards, and architectures that are in use today.
b. Identify the basic concepts of LAN and WAN technologies and topologies.
c. Describe different components and requirements of network protocols.
d. Discuss the concepts and the “building blocks” of today’s data communication networks such as switches, routers, and cabling.
e. Explain the operation and function of 802.1 devices and protocols.
f. Describe the necessary hardware (switches and routers) and components (routing algorithms and protocols) used to establish communication between multiple networks.
g. Analyze the effect of various topologies, applications and devices on network performance topics such as latency, jitter, response time, window size, connection loss and quality of service.

ITE-NET-06 Application networking services
Minimum instructional hours: 6 hours

Competencies:

a. Describe web software stack technologies such as LAMP solution stack (Linux, Apache HTTP server, MySQL, PHP/Perl/Python).
b. Describe the key components of a web solution stack using LAMP as an illustrative example.
c. Explain two roles and responsibilities of clients and servers for a range of possible applications.
d. Select three tools that will ensure an efficient approach to implementing various client-server possibilities.
e. Design and implement a simple interactive web-based application (for example, a simple web form that collects information from the client and stores it in a file on the server).
f. Contrast peer-to-peer, client-server, and cloud networks.
g. Describe two web technologies such as dynamic HTML and the client-side model, server-side model.
h. Describe two characteristics of web servers such as handling permissions, file management, capabilities of common server architectures.
i. Explain the support tools for website creation and web management.
j. Explain the architecture and services of email systems.
k. Explain the role of networking in database and file service applications.
l. Demonstrate the working process of DNS, steps of a resolver looking up a remote name.
m. Analyze the impact on the world-wide web portion of the internet if the majority of all routers ceased to function.
n. Explain the problem of distributing content, the architecture of content distribution network and peer-to-peer network.

ITE-NET-07 Network management and security
Minimum instructional hours: 8 hours

Competencies:

a. Explain three main issues related to network management.
b. Discuss four typical architectures for network management including the management console, aggregators and device agents.
c. Demonstrate the management of a device such as an enterprise switch through a management console.
d. Compare various network management techniques as they apply to wired and wireless networks such as topics on devices, users, quality of service, deployment, and configuration of these technologies.

e. Discuss the address resolution protocol (ARP) for associating IP addresses with MAC addresses.
f. Explain the concepts of domain names and domain name systems (DNS).
g. Explain the dynamic host configuration protocol (DHCP).
h. Describe two issues related to internet service providers (ISPs).
i. Explain two quality of service issues such as performance and failure recovery.
j. Describe ad hoc networks.
k. Explain troubleshooting principles and techniques related to networks.
l. Describe management functional areas related to networks.

ITE-WMS Web and Mobile Systems

[25 hours]

Domain Scope

1. Web-based applications including related software, databases, interfaces, and digital media
2. Mobile applications including related software, databases, interfaces, and digital media
3. Contemporary web technologies, semantic web, social media

ITE-WMS Subdomains

ITE-WMS-01 History and overview
Minimum instructional hours: 1 hour

Competencies:

a. Outline the history of the world wide web.
b. Outline the history of mobile devices and applications.
c. Describe the structure of the world wide web as interconnected hypertext documents.

ITE-WMS-02 Technologies
Minimum instructional hours: 5 hour

Competencies:

a. Describe the importance of the HTTP protocol in web applications.
b. Build a simple web site that organizes information effectively.
c. Validate HTML/XHTML documents.
d. Use a structured markup syntax such as XML or JSON to show how to display a document in a web application.
e. Use two presentation technologies such as Cascading Style Sheets (CSS) in a website.
f. Discuss data entry and validation techniques in client-side vs. server-side programming.
g. Contrast client-side with server-side security issues.
h. Describe the use of server-side backend databases in websites and web and mobile applications.
i. Describe five technologies used in web services, including open source languages and packages, proprietary languages and packages, and enterprise web development and distributed web applications.
j. Compare open source and proprietary server software for web and mobile systems.
k. Discuss two web standards and standards bodies including the world wide web Consortium (W3C).
l. Discuss web standards in terms of specifications, guidelines, software, and tools.

ITE-WMS-03 Digital media
Minimum instructional hours: 5 hour

Competencies:

a. Identify three digital libraries.
b. Describe three media acquisition tools and techniques to create and record media, capture, digitize, and sample media contents, and multimedia authoring.
c. Compare three graphic media file format characteristics such as color depth, compression and CODEC.
d. Compare two streaming media file format characteristics such as color depth, bit rate, CODEC and server requirements.
e. Contrast four concepts of graphic file formats including lossy/lossless compression, color palettes and CODECs.
f. Choose one graphic file type that matches the image characteristics.
g. Identify two time-based media types commonly used on the web.
h. Discuss three issues involved in deploying and serving media content.

ITE-WMS-04 Applications concepts
Minimum instructional hours: 5 hour

Competencies:

a. Discuss three constraints that mobile platforms put on developers.
b. Discuss performance vs. power tradeoff.
c. Contrast mobile programming, web programming, and general purpose programming.
d. Describe two characteristics that enhance usability of a web site.
e. Describe two issues involved in developing a web interface.
f. Discuss the use of proprietary media and interaction technologies such as Flash, Active X, RealMedia, and QuickTime.

ITE-WMS-05 Development frameworks
Minimum instructional hours: 4 hour

Competencies:

a. Identify three issues involved in website implementation and integration.
b. Explain the importance of interfacing websites to underlying databases.
c. Design a web application that uses server-side cookies.
d. Implement a simple web application.
e. Use accepted standards to ensure that user input on web pages do not affect server-side processes.
f. Discuss the development process and technologies used in mobile development such as languages, IDEs, and emulators.
g. Develop a mobile application.

ITE-WMS-06 Vulnerabilities
Minimum instructional hours: 3 hour

Competencies:

a. Describe three browser security models including same-origin policy and thread models in web security.
b. Discuss the concept of web sessions, secure communication channels such as TLS and the importance of secure certificates, authentication including single sign-on such as OAuth and SAML.
c. Describe two common types of vulnerabilities and attacks in web and mobile applications, and defenses against them.
d. Use two client-side security capabilities in an application.
e. Identify websites that are using web page graphics as web beacons.
f. Name two ways in which cookies can be used to compromise user privacy, and methods of security for cookies.
g. Describe two ways to increase the trustworthiness of a website or mobile application, such as security certificates.
h. Describe the use of public key encryption to enhance security.
i. Explain what denial of service attacks are and how they are carried out.

ITE-WMS-07 Social software
Minimum instructional hours: 2 hour

Competencies:

a. Describe how the web has given rise to the emergence of online communities.
b. Explain the difference between asynchronous and synchronous communication.
c. Contrast the characteristics of various web- and mobile-based communication media, such as social media sites like Facebook and Twitter, discussion boards, wikis, blogs, and chat-rooms.

ITE-IMA Information Management

[40 hours]

Domain Scope

1. Tools and techniques for efficient data modeling, collection, organization, retrieval and management
2. Tools and techniques for extracting information from data to make it meaningful to an organization
3. Development, deployment of data and information systems to support an organization
4. Safety and security issues associated with data and information

ITE-IMA Subdomains

ITE-IMA-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Explain one recent feature affecting data storage and retrieval.
b. Explain two advantages of a database approach compared to traditional file processing.
c. Explain two ways in which the growth of the internet and demands for information for users outside the organization (customers and suppliers) impact data handling and processing.
d. Identify two database models and their evolution.

ITE-IMA-02 Data-information Concepts

Minimum instructional hours: 6 hours

Competencies:

a. Explain a role of data, information, and databases in organizations.
b. Differentiate the following key terms: information, data, database, database management system, metadata, and data mining.
c. Define data quality, accuracy and timeliness, and explain how their absence will impact organizations.
d. Describe two mechanisms for data collection and their implications (automated data collection, input forms, sources).
e. Explain three basic issues of data retention, including the need for retention, physical storage, backup and security.

ITE-IMA-03 Data modeling

Minimum instructional hours: 7 hours

Competencies:

a. Design an entity relationship diagram based on appropriate business rules for a given scenario.
b. Describe the relationship between a logical model and a physical model.
c. Explain importance of database constraints.
d. Differentiate relational and dimensional data modeling (OLTP vs OLAP).
e. Design a physical model for the best performance including impact of normalization and indexes.

ITE-IMA-04 Database query languages

Minimum instructional hours: 9 hours

Competencies:

a. Create, modify and query database objects using the structured query language (SQL).
b. Filter and sort data using various clauses including ‘where’, ‘order by’, ‘between’, ‘like’, ‘group by’ and ‘having’ for a given database.
c. Use ‘joins’ and embedded SQL techniques to select data across multiple tables.
d. Perform calculations in a query using calculated fields and aggregate functions.
e. Create updatable and non-updatable views for a given database.

ITE-IMA-05 Data organization architecture

Minimum instructional hours: 8 hours

Competencies:

a. Demonstrate ‘select’, ‘project’, ‘union’, ‘intersection’, ‘set difference’, and ‘natural join’ relational operations using simple example relations provided.
b. Contrast relational databases concepts and non-relational databases including object-oriented, XML, NewSQL and NoSQL databases.
c. Explain the relationship between functional dependencies and keys, and give one example.
d. Define data integrity and provide two examples of entity and referential integrity.
e. Explain how data fragmentation, replication and allocation affect database performance.

ITE-IMA-06 Special-purpose databases
Minimum instructional hours: 2 hours

Competencies:

a. Describe two major concepts of object oriented, XML, NewSQL and NoSQL databases.
b. Identify online analytical processing and data warehouse systems.
c. Describe two methods of data mining.

ITE-IMA-07 Managing the database environment
Minimum instructional hours: 5 hours

Competencies:

a. Distinguish between data administration and database administration.
b. Describe two tasks commonly performed by database administrators.
c. Explain the concept of database security and backup/recovery.
d. Identify two characteristics for using metadata in a database environment.
e. Manage database users, roles and privileges.

ITE-SWF Software Fundamentals

[30 hours]

Domain Scope

1. Skills and concepts essential to good programming practice and problem solving
2. Fundamental programming concepts, basic data structures, and algorithmic processes
3. Event-driven programming, object-oriented programming

ITE-SWF Subdomains

ITE-SWF-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Describe two recent features how the creation of software has changed our lives.
b. Explain how software has helped people, organizations, and society to solve problems.
c. Explain two advantages on ways software has created new knowledge.

ITE-SWF-02 Concepts and techniques

Minimum instructional hours: 5 hours

Competencies:

a. Use multiple levels of abstraction to write programs (constants, expressions, statements, procedures, parameterization, and libraries).
b. Select appropriate built-in data types and library data structures (abstract data types) to model, represent, and process program data.
c. Use procedures and parameterization to reduce the complexity of writing and maintain programs and generalize specific solutions.
d. Identify multiple levels of hardware abstractions (from gates and chips to special purpose cards and storage devices) and software abstractions (from source code and integrated components to program and running processes) that are used when writing and executing programs.
e. Create a new program by modifying and combining existing programs.

ITE-SWF-03 Problem-solving strategies

Minimum instructional hours: 3 hours

Competencies

a. Explain abstractions used to represent digital data.
b. Develop abstractions when writing a program or an IT artifact.
c. Apply decomposition strategy to design a solution to a complex problem.
d. Explain appropriateness of iterative and recursive problem solutions.
e. Write programs that use iterative and recursive techniques to solve computational problems.

ITE-SWF-04 Program development

Minimum instructional hours: 8 hours

Competencies

a. Develop a correct program to solve problems by using an iterative process, documentation of program components, and consultation with program users.
b. Use appropriate abstractions to facilitate writing programs: collections, procedures, application programming interfaces, and libraries.
c. Evaluate how a program is written in terms of program style, intended behavior on specific inputs, correctness of program components, and descriptions of program functionality.
d. Develop a program by using tools relevant to current industry practices: version control, project hosting, and deployment services.
e. Use two effective collaboration strategies that take into account multiple perspectives, diverse talents, sociocultural experiences.

ITE-SWF-05 Fundamental data structures

Minimum instructional hours: 4 hours

Competencies:

a. Write programs that use data structures (built-in, library, and programmer-defined): strings, lists, and maps.
b. Analyze the performance of different implementations of data structures.
c. Select appropriate data structure for modeling a given problem.
d. Explain appropriateness of selected data structures.

ITE-SWF-06 Algorithm principles

Minimum instructional hours: 6 hours

Competencies

a. Describe why and how algorithms solve computational problems.
b. Create algorithms to solve a computational problem.
c. Explain how programs implement algorithms in terms of instruction processing, program execution, and running processes.
d. Apply two appropriate mathematical concepts in programing: expressions, abstract data types, recurrence relations, and formal reasoning on algorithm's efficiency and correctness.
e. Analyze empirically the efficiency of an algorithm.

ITE-SWF-07 Modern app programming

Minimum instructional hours: 3 hours

Competencies

a. Create web and mobile apps with effective interfaces that respond to events generated by rich user interactions, sensors, and other capabilities of the computing device.
b. Analyze usability, functionality, and suitability of an app program.
c. Collaborate in the creation of interesting and relevant apps.
d. Build and debug app programs using standard libraries, unit testing tools, and debuggers.
e. Evaluate readability and clarity of app programs based on program style, documentation, pre- and post-conditions, and procedural abstractions.

ITE-SIA System Integration and Architecture

[20 hours]

Domain Scope

1. Skills and tools to gather requirements, source code development, evaluation and integration of components into a single system, and system validation
2. Fundamentals of project management and the interplay between IT applications and related organizational processes
3. System integration issues, including integration in a system of systems and federation of systems, role of architectures in systems integration, performance and effectiveness

ITE-SIA Subdomains

ITE-SIA-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Define the meaning of system integration and architecture.
b. Explain when system integration and architecture became part of an IT curriculum.
c. Describe the system integration from the business perspective.

ITE-SIA-02 Requirements

Minimum instructional hours: 4 hours

Competencies:

a. Identify the stakeholders of a system and formulate their needs.
b. Compare the various requirements modeling techniques.
c. Distinguish between non-functional and functional requirements.
d. Classify the roles played by external users of a system.
e. Explain and give examples of use cases.
f. Explain the structure of a detailed use case.
g. Detail a use case based on relating functional requirements.
h. Describe the types of event flows in a use case and under which conditions they occur.
i. Explain how requirements gathering fits into a system development lifecycle.
j. Explain how use cases drive testing throughout the system lifecycle.

ITE-SIA-03 System architecture

Minimum instructional hours: 2 hour

Competencies:

a. Explain "architecture" in the context of system integration and architecture. (IEEE Std. 1471).
b. Justify how complex systems can be represented using architectural views and how this facilitates system evolution over time.
c. Explain how some specific architectural views relate to the system lifecycle.
d. Give two examples of architectural frameworks and associated best practice models (SOA, Zachman Framework, ITIL, COBIT, ISO 20,000).
e. Provide three examples of modeling tools that support description and management of architectural views.

ITE-SIA-04 Acquisition and sourcing

Minimum instructional hours: 4 hours

Competencies:

a. Differentiate between build and buy in software and hardware acquisition.
b. Explain two advantages and drawbacks of building and buying in general.
c. Differentiate between in-sourcing and out-sourcing for the acquisition of IT services, including support.
d. Contrast the advantages and drawbacks of in-sourcing and out-sourcing in general.
e. Explain three importance of testing, evaluation and benchmarking in any IT sourcing decision.
f. Explain two primary components in a request for proposal (RFP).
g. Contrast the advantages and drawbacks of using RFPs in an IT sourcing decision.
h. Explain the importance of a well-structured contract in any IT sourcing decision.
i. Given a RFP, recommend and justify one or more products that satisfy the criteria of the RFP.

ITE-SIA-05 Testing and quality assurance
Minimum instructional hours: 4 hours

Competencies:
a. Give two examples of current testing standards.
b. Explain the various components of usability testing.
c. Discuss three ways to execute and evaluate an acceptance test.

ITE-SIA-06 Integration and deployment
Minimum instructional hours: 5 hours

Competencies:
a. Define integration in terms of components and interfaces.
b. Give two examples of middleware platforms.
c. Discuss three advantages and disadvantages of some middleware platforms.
d. Describe two major considerations for the selection of an enterprise integration platform.
e. Give one example of integration using the “wrapper” approach.
f. Give one example of integration using the “glue code” approach.
g. Provide an example of how a framework facilitates integration of components.
h. Explain how the data warehouse concept relates to enterprise information integration.
i. Provide two examples of how integration choices affect testing and evaluation.

ITE-SAM System Administration and Maintenance

[20 hours]

Domain Scope

1. Design, selection, application, deployment, and management of computing systems to support an organization
2. Skills and concepts essential to the administration of operating systems, networks, software, file systems, file servers, web systems, database systems, and system documentation, policies, and procedures
3. Education and support of users of computing systems

ITE-SAM Subdomains

ITE-SAM-01 History and overview
Minimum instructional hours: 1 hour

Competencies:

a. Define the meaning of SAM.
b. Describe role of SAM in the organizational context.
c. Define the concept 'administrative domain'.
d. Explain the advantages of a systems administration plan for all devices in an administrative domain.
e. Identify the responsibilities associated with resource administration and management.

ITE-SAM-02 Administrative Activities
Minimum instructional hours: 5 hours

Competencies:

a. Identify situations in which administrative activities are required.
b. Identify situations which interfere with administrative activities.
c. Design and implement a user and group administrative structure that allows the users to effectively use system resources.
d. Design training material on administrative policies for different types of users.
e. Develop project plans for major system administration activities.
f. Install and configure appropriate software and other resources.
g. Install update patches in devices and other resources in the system.
h. Compare alternative vendors of systems resources.

ITE-SAM-03 Administrative Domains
Minimum instructional hours: 4 hours

Competencies:

a. Describe the scope of each administrative domain in a system (e.g. web, network, database, OS, cloud, and support).
b. Develop two policies for each domain that allow for smooth interaction between domains without sacrificing security.
c. Explain the concept "resource" in the systems context.
d. Explain the need for policies governing systems.
e. Develop two plans which assign the appropriate resources to each domain.

ITE-SAM-04 Performance Analysis
Minimum instructional hours: 3 hours

Competencies:

a. Justify the need for performance analysis of a networked system.
b. Compare the various performance analysis tools.
c. Explain why metrics such as power consumption are significant in performance evaluation.
d. Use data analytics to discover the source of performance problems in a system.

ITE-SAM-05 Backup and Recovery
Minimum instructional hours: 3 hours

Competencies:

a. Design and implement a backup and restore strategy for a system.
b. Develop a disaster recovery plan for a small enterprise.
c. Confirm the accuracy and completeness of a backup.

ITE-SAM-06 Applications of System Administration
Minimum instructional hours: 4 hours

Competencies:

a. Explain two benefits of content management within an organization.
b. Explain the need for content deployment policies in a system.
c. Explain two advantages of automated update deployment technologies.
d. Develop a plan and policies for a networked system in an application domain (e.g. health care organization).
e. Develop a plan and policies for a network that includes low capacity embedded devices (e.g. a smart home).

ITE-PFT Platform Technologies

[15 hours]

Domain Scope

1. Comparison of various operating systems available, including their respective characteristics, advantages and disadvantages
2. Selection, deployment, integration and administration of platforms or components to support the organization's IT infrastructure
3. Fundamentals of hardware and software and how they integrate to form the essential components of IT systems

ITE-PFT Subdomains

ITE-PFT-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Describe the development of hardware computing platforms.
b. Describe the development of operating system platforms.

ITE-PFT-02 Operating systems

Minimum instructional hours: 7 hours

Competencies:

a. Define the necessary components and functions of an operating system.
b. Demonstrate the ability to use both Windows and Unix-class systems.
c. Describe two similarities and differences between Windows and Unix-class systems.
d. Explain three main benefits of using scripts to perform operating systems tasks.

ITE-PFT-03 Computing infrastructures

Minimum instructional hours: 2 hours

Competencies:

a. Estimate the power requirements for a computer system.
b. Explain the need for power and heat budgets within an IT environment.
c. List two various types of servers required within organizations.
d. Describe the need for hardware and software integration.

ITE-PFT-04 Architecture and organization

Minimum instructional hours: 3 hours

Competencies*:*

a. Describe how numbers and characters are represented in a computer.
b. Draw a block diagram, including interconnections, of the main parts of a computer.
c. Describe how a computer stores and retrieves information to/from memory and hard drives.
d. Define the terms: bus, handshaking, serial, parallel, data rate.

ITE-PFT-05 Application execution environment

Minimum instructional hours: 2 hours

Competencies:

a. Design a simple finite state machine with at least 6 states and 4 conditional branches, then build and troubleshoot it.
b. Complete a comparison in the performance of two different computers with two different operating systems.
c. List three advantages and disadvantages of the five main hardware implementation options.

ITE-IST Integrated Systems Technology

[20 hours]

Domain Scope

1. Scripting languages, their uses and architectures
2. Application programming interfaces
3. Programming practices to facilitate the management, integration and security of the systems that support an organization

ITE-IST Subdomains

ITE-IST-01 History and overview
Minimum instructional hours: 1 hour

Competencies:

a. Describe the importance of integrating various modules into a working system.
b. Explain why integration is an important function of all IT professionals.

ITE-IST-02 Data mapping and exchange
Minimum instructional hours: 4 hours

Competencies:

a. Define the term, metadata.
b. Describe the characteristics of each of the following data encoding schemes, and recommend under what conditions each should be used: ASCII, EBCDIC, and Unicode.
c. Tell how XML and the document object model are being used to integrate and exchanging data between systems.
d. Use DTD to create a document definition for a data structure. Given a DTD for data structure create a XML document with real data.
e. Describe how XSL, XSLT and XPath are used to transform data streams.

ITE-IST-03 Intersystem communication protocols
Minimum instructional hours: 4 hours

Competencies:

a. Describe the different types of architectures for integrating systems.
b. Define the role of DCOM, CORBA, and RMI in distributed processing.
c. Describe how web services are used to integrate disparate applications in an organization. Describe the role of the WSDL, SOAP, and UDDI architectures in creating and using web services.
d. Describe the role of socket programming in communicating between systems. Contrast the protocols and uses of TCP/IP sockets and Datagram sockets.
e. Describe the purpose of message and queuing services and how they work. List the protocol used by one messaging service (e.g. JMS).
f. List two commonly used low level data communications protocols (e.g., RS232), state conditions for when each protocol should be used, and outline the protocol for one low level communication protocol.

ITE-IST-04 Integrative programming
Minimum instructional hours: 4 hours

Competencies:

a. Define the importance of using design patterns.
b. List the motivation for using each of the following design patterns: MVC, singleton, factory method, façade, proxy, decorator, and observer.
c. Describe what a programming interface is and why it is important to programming.
d. Give one example of where the use of a programming interface simplified the development of a system.
e. Define the concept of inheritance and describe how it can be applied to encourage code reuse.
f. Design an abstract class and use inheritance to create a class that extends the abstract class.
g. Design, develop and test an application that uses the abstract class.

ITE-IST-05 Scripting techniques
Minimum instructional hours: 4 hours

Competencies:

a. Identify key scripting languages used for web scripting, servers-side scripting and operating system scripting.
b. Write, debug and test a script that includes selection, repetition and parameter passing.

ITE-IST-06 Defensible integration
Minimum instructional hours: 3 hours

Competencies:

a. Contrast evidence-based security vs. code access security.
b. Define three goals of secure coding.
c. Give two guidelines for authenticating and defining permissions to systems services and resources.
d. For each of the following "best secure coding" practices, give an example of a problem that can occur when the practice is not followed and then describe how to overcome the problem:
    1. Preventing buffer overflow
    2. Securing state data
    3. Securing method access
    4. Wrapper code
    5. Unmanaged code
    6. Validation of user input
    7. Remoting considerations
    8. Protected objects
    9. Serialization
    10. Robust error handling

ITE-CSP Cybersecurity Principles

[40 hours]

Domain Scope

1. Identification of policies, mechanisms, services, and countermeasures related to cybersecurity
2. Cyber-attacks, cyber-detection, services and operational issues, security mechanisms and detection
3. Vulnerabilities, threats, risks, concealment, cyphers and deciphers, encryption, and decryption
4. Malware operations, mitigation, and recovery
5. Data and information security, security breaches, and reporting requirements

ITE-CSP Subdomains

ITE-CSP-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Identify significant continuing trends in the history of cybersecurity.
b. Identify two significant cybersecurity events since 1980.
c. List two significant cybersecurity advances.
d. Discuss the historical context for today's cybersecurity problems.

ITE-CSP-02 Policy goals and mechanisms

Minimum instructional hours: 2 hours

Competencies:

a. Identify governance structures through which cybersecurity policy goals are created and promulgated.
b. Provide three multiple definitions for the word "policy" within a cybersecurity context.
c. Identify current cybersecurity policy objectives and goals.
d. Discuss vulnerability notification and repair policies, important policy issues to consider in computer security, including issues associated with fixing or not fixing vulnerabilities and disclosing or not disclosing vulnerabilities.
e. Discuss the implications of relying on open design or the secrecy of design for security.
f. Discuss why cybersecurity is a societal imperative.

ITE-CSP-03 Security services, mechanisms and countermeasures

Minimum instructional hours: 4 hours

Competencies:

a. Analyze the tradeoffs of balancing key security properties (Confidentiality, Integrity, and Availability).
b. Describe the concepts of risk, threats, vulnerabilities and attack vectors (including the fact that there is no such thing as perfect security).
c. Define the concept of "countermeasures" and provide examples for specific threats.
d. Define the concept of "continuous monitoring" and provide examples.
e. Explain the concept of identity management and its importance.
f. Explain the concepts of authentication, authorization, and access control.
g. Explain the benefit of two-factor authentication, including the use of biometrics.
h. Define application 'whitelisting'.
i. Identify the costs and tradeoffs associated with security that a company implements into a product.

ITE-CSP-04 Cyber-attacks and detection

Minimum instructional hours: 4 hours

Competencies:

a. Define the roles of prevention, deterrence, and detection mechanisms.
b. Identify password guessing, port scanning, SQL injection probes, and other cyberattacks in log files.
c. Discuss the role and limitations of signature-based and behavioral-based anti-virus technology.
d. Explain two differences between host-based and network-based intrusion detection systems.
e. Create three rules for a network-based intrusion detection system that will protect against specific known attacks.
f. Discuss the use of deception by malware to evade security mechanisms.

ITE-CSP-05 High assurance systems

Minimum instructional hours: 4 hours

Competencies:

a. Explain the concept of trust and trustworthiness.
b. Describe the principle of least privilege and isolation as applied to system design.
c. Summarize the principle of fail-safe and deny-by-default.
d. Describe the concept of mediation and the principle of complete mediation.
e. Explain the concept of trusted computing including trusted computing base and attack surface and the principle of minimizing trusted computing base.
f. Describe commercial approaches to delivering high-assurance services, including SE Linux, Security Enhanced hypervisors, role-based access systems, and digital signatures applied to code and data.
g. Discuss the role of formal methods in creating high assurance software and systems.
h. Discuss the role of Trusted Platform Modules (TPMs) in creating high assurance systems.

ITE-CSP-06 Vulnerabilities, threats and risk

Minimum instructional hours: 5 hours

Competencies:

a. Explain the relationship between vulnerabilities, threats and risk.
b. Give two examples of how security mechanisms can contain vulnerabilities.
c. Identify a risk management framework that is in use today.
d. Identify the role of penetration testing; use penetration-testing tools to identify a vulnerability.
e. Discuss three benefits of defense in depth, i.e. having multiple layers of defenses.
f. Describe security issues that arise at boundaries between multiple components.
g. Determine if software installed on a server or network component is listed in the National Vulnerability Database.
h. Distinguish vulnerabilities, threats and risks that are distinct to network infrastructure, cloud computing servers, desktop computers, and mobile devices.
i. Demonstrate a buffer-overflow attack against a server that reads an unbounded data into a fixed-size data structure.
j. Demonstrate a cross-site scripting attack against a server that does not properly sanitize user input prior to displaying the results in a browser.

ITE-CSP-07 Anonymity systems

Minimum instructional hours: 2 hours

Competencies:

a. Identify anonymous communication and payment systems currently in use, their limitations.
b. Identify legitimate and illicit uses of anonymity systems.
c. Define three policies for prohibiting or using anonymity systems within an organization.
d. Demonstrate the use of an anonymity system (e.g. Tor).
e. Identify information not protected by a communications anonymity system.
f. Evaluate the impact of search queries on maintaining anonymity.
g. Evaluate the implications of DNS queries on maintaining anonymity.

ITE-CSP-08 Usable security

Minimum instructional hours: 3 hours

Competencies:

a. Discuss the concept of "psychological acceptability" and the importance of usability in security mechanism design.
b. Describe the issues of trust in interface design with an example of a high and low trust system.
c. Design a user interface for a security mechanism.
d. Analyze a security policy and/or procedures to show where it considers, or fails to consider, human factors.
e. Critique the ability of complex password policies to achieve the desired goal of preventing unauthorized access to sensitive systems.
f. Discuss three difference between erasing pointers to information and overwriting the data contents, with application to file systems, databases, and cloud storage.
g. Evaluate the effectiveness of an authentication mechanism from the perspective of a person who is visually impaired.

ITE-CSP-09 Cryptography overview
Minimum instructional hours: 3 hours

Competencies:

a. Define the terms encryption, decryption, key, public key cryptography, symmetric cryptography, algorithm, key length, key escrow, key recover, key splitting, random number generator, nonce, initialization vector, cryptographic mode, plaintext, cipher text, S/MIME, PGP, IPsec, TLS.
b. Identify the algorithms DES, 3DES, AES, MD5, SHA-1, SHA-2, SHA-3.
c. Distinguish encryption, digital signatures, and hash functions.
d. Compare encryption for data at rest and data in motion.
e. Distinguish between block-level encryption, file-level encryption, and application-level encryption for encrypted storage.
f. Describe why it is preferred to use validated, proven algorithms and implementations rather than developing new ones.

ITE-CSP-10 Malware fundamentals
Minimum instructional hours: 2 hours

Competencies:

a. Define “malware” and distinguish the categories and uses of malware.
b. Identify malware infection mechanisms, malware countermeasures (e.g., signature-based detection, behavioral detection).
c. Identify appropriate locations within organizational information systems to provide protection from malware.
d. Inspect a system (network, computer, or application) for the presence of malware.
e. Identify two techniques for safely isolating malware samples from infected systems and classifying the sample.

ITE-CSP-11 Mitigation and recovery
Minimum instructional hours: 3 hours

Competencies:

a. Discuss a risk mitigation and incident recovery plan.
b. Identify the options for mitigating a malware infection on an enterprise client and an enterprise server.
c. Describe the managerial and forensic steps for recovery after detecting a hostile insider.
d. Contrast backup and recovery plans designed to protect against natural disasters from those designed to protect against hostile actors.
e. List two examples of the steps taken after a credential is lost or compromised.
f. Describe approaches for mitigating supply chain risks.

ITE-CSP-12 Personal information
Minimum instructional hours: 2 hours

Competencies:

a. Define the terms Personal Information, Personally Identifiable Information, De-Identification, Anonymization, Pseudonym, Masking, Unmasking,
b. Identify the Fair Information Practices.
c. Classify two categories of personal information according to privacy and disclosure risk.
d. Discuss two policies for collecting, processing, storing, sharing, and disposing of personal information.
e. Discuss the role and limitations of encryption for protecting personal information.
f. Discuss three policies and technologies for isolating personal data from enterprise data.
g. Discuss two approaches for controlling access to personal information.

ITE-CSP-13 Operational issues
Minimum instructional hours: 4 hours

Competencies:

a. Describe the steps for determining the exposure and planning recovery of a lost laptop and mobile device.
b. Identify two standards that would apply to an organization’s information security posture.
c. Evaluate potential vendors with respect to their security offerings.
d. Track emerging threats, vulnerabilities and migrations.
e. Develop a continuing education program.
f. Discuss recruitment, retention and retaining of security personnel.

ITE-CSP-14 Reporting requirements

Minimum instructional hours: 1 hour

Competencies:

a. Identify legal and regulatory requirements for sharing of threat and breach information.
b. Contrast different vulnerability disclosure policies, including “full disclosure,” and “responsible disclosure.”
c. Discuss the need and security advantages of security personnel sharing information about breaches with employees, and the need to balance employee notification with the need to maintain confidentiality during investigations.

ITE-GPP Global Professional Practice

[25 hours]

Domain Scope

1. Historical, social, professional, ethical, and legal aspects of computing
2. Importance of identifying and understanding essential skills required for a successful career within the industry
3. Identification of ways teamwork integrates throughout IT and ways IT supports an organization
4. Social and professional contexts of information technology and computing, and adherence to ethical codes of conduct
5. Importance of business professional oral and written communication skills

ITE- GPP Subdomains

ITE-GPP-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Describe the nature of professionalism and its place in the field of information technology.
b. Identify two contributors and relate their achievements to social and professional issues.
c. Contrast between ethical and legal issues as related to information technology.
d. Identify essential skills required for a successful IT career.
e. Describe how IT uses or benefits from social and professional issues.

ITE-GPP-02 Professional issues and responsibilities

Minimum instructional hours: 2 hours

Competencies:

a. Identify the professional context of information technology and computing and adherence to ethical codes of conduct.
b. Explain two historical, professional, ethical, and legal aspects of computing.
c. Identify three ways teamwork integrates throughout IT and supports an organization.

ITE-GPP-03 IT governance and resource management

Minimum instructional hours: 2 hours

Competencies:

a. Discuss the expanding role of IT governance and its effect on business.
b. Explore management issues in IT governance.
c. Compare organizational cultures and their impact on IT governance.
d. Explain the concept “resource” in the systems context.
e. Justify the appropriate resources needed to administer the system.
f. Contrast two alternative vendors of system resources.
g. Explain the need for policies governing systems.
h. Develop naming conventions for the resources in a system.
i. Explain why users need to be trained on policies in order to effectively use the resources.
j. Develop two appropriate policies and procedures to manage resources in a system.

ITE-GPP-04 Risk identification and evaluation

Minimum instructional hours: 2 hours

Competencies:

a. Discuss the role of risk to an organization and ways to identify key risk factors.
b. Understand how to evaluate various risks and appropriate actions.
c. Describe the effect of risk on an organization.
d. Construct a risk matrix.

ITE-GPP-05 Environmental issues
Minimum instructional hours: 2 hours

Competencies:
a. Explore knowledge, strategy and design issues on how to develop green IT policies, standards and learn to identify green IT.
b. Identify two frameworks for green computing.
c. Define two uses of green computing for improving energy efficiency.

ITE-GPP-06 Ethical, legal and privacy issues
Minimum instructional hours: 2 hours

Competencies:
a. Discuss the history of our nation's privacy, legal and ethical considerations.
b. Discuss the role of legal issues within IT as it relates to business.
c. Identify two ways that technology is aiding and curtailing our privacy.
d. Develop a computer use policy with enforcement measures.
e. Discuss if the ECPA act, as well as whether our existing laws need to be modified to keep up with technology.
f. Develop a computer use policy which includes privacy, legal and ethical considerations for all employees.

ITE-GPP-07 Intellectual property
Minimum instructional hours: 3 hours

Competencies:
a. Describe the foundations of intellectual property.
b. Outline two of the transnational issues concerning intellectual property.
c. Distinguish among employees, contractors, and consultants and the implications of each status.
d. Discuss the historical development of software patents and compare with other forms of intellectual property protection for software.

ITE-GPP-08 Project management principles
Minimum instructional hours: 3 hours

Competencies:
a. Explain the key components of a project plan.
b. Describe the importance of a cost/benefit analysis to the successful implementation of a project plan.
c. Identify two roles and responsibilities for key project personnel and stakeholders.
d. Discuss appropriate project planning and tracking tools.
e. Define two issues involved in creating a project schedule.
f. Explain two roles and responsibilities for key project personnel and stakeholders.
g. Explain how to identify the lessons learned in a project closeout and review session.

ITE-GPP -09 Communications
Minimum instructional hours: 3 hours

Competencies:
a. Develop two strategies for effective professional communication in writing and in speaking.
b. Write well-organized technical reports that are structured according to acceptable standards.
c. Learn to communicate effectively and build a rapport with an audience.
d. Define the role of communications within IT as well as in building relationships with the business.
e. Explain two appropriate visual aids for effective communications.
f. Identify two essential skills for communicating within a team environment.

ITE-GPP-10 Teamwork and conflict management
Minimum instructional hours: 2 hours

Competencies:
a. Describe the meaning of multidisciplinary teams.
b. Define two skill sets necessary to function effectively in a team environment.
c. Explore two ways in which industry approaches teamwork toward a common goal.
d. Identify the basics of conflict management.
e. Describe three ways that conflict management aids in building stronger teams.

ITE-GPP-11 Employability skills and careers in IT
Minimum instructional hours: 2 hours

Competencies:
a. Describe the meaning of multidisciplinary teams.
b. Define two skill sets necessary to function effectively in a team environment.
c. Explore three ways in which industry approaches teamwork toward a common goal.
d. Describe two computer IT projects where teamwork approaches are important.

ITE-GPP-12 Information systems principles
Minimum instructional hours: 1 hour

Competencies:
a. Describe two main concepts of business analysis.
b. Explain how information systems supports business requirements.
c. Describe the system development life cycle, its phases, and models.
d. Evaluate the effectiveness and efficiency of a system.
e. Identify two high-level IT strategies to avoid obstacles to achieve business goals.

ITE-UXD User Experience Design

[20 hours]

Domain Scope

1. Understanding of advocacy for the user in the development of IT applications and systems
2. Development of a mind-set that recognizes the importance of users, context of use, and organizational contexts
3. Employment of user-centered methodologies in the design, development, evaluation, and deployment of IT applications and systems
4. User and task analysis, human factors, ergonomics, accessibility standards, experience design, and cognitive psychology

ITE-UXD Subdomains

ITE-UXD-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Indicate when human factors first became an issue in computer hardware and software design.
b. Define the meaning of human-computer interaction or HCI.
c. Define the meaning of user experience design or UXD.
d. Describe the evolution from human factors to User Experience Design (UX).
e. Contrast the physical and non-physical aspects of UXD.
f. Identify three modern high-tech computing technologies that present UXD challenges.
g. Describe two reasons for making UXD an essential part of the information technology discipline.

ITE-UXD-02 Human factors in design

Minimum instructional hours: 5 hours

Competencies:

a. Explain the conceptual terms for analyzing human interaction with products (e.g., affordance and feedback).
b. Analyze two different user populations or user cultures with regard to their abilities to use software and hardware products.
c. Explain the importance of user abilities and characteristics in the usability of products.
d. Illustrate two ways cognitive and social principles apply to product design.
e. Illustrate three ways that physical aspects of product design affect usability.
f. Identify two goals, activities and tasks related to an UX project.
g. Describe how creative innovation techniques such as brainstorming can lead to optimal user interfaces.

ITE-UXD-03 Effective interfaces

Minimum instructional hours: 2 hours

Competencies:

a. Explain how the user interface (UI) and interaction affect usability.
b. Design an interface that effectively employs localization and globalization technologies.
c. Adapt an interface to more effectively relate to users' characteristics (i.e., age, education, cultural differences, etc.).
d. Design a user experience using storyboarding techniques.
e. Develop and justify a low-fidelity prototype for a system or product.
f. Develop and justify a high-fidelity prototype for a system or product.
g. Explain the advantages of user interface modalities other than windows, icons, menus and pointers in some situations.

ITE-UXD-04 Application domain aspects

Minimum instructional hours: 3 hours

Competencies:

a. Describe two different types of interactive environments.
b. Describe three differences in developing user interfaces for different application environments and types of services.
c. Explain the connection between the design of a user interface and a model of user domain expertise.
d. Match descriptions of cognitive models with the model names.
e. Apply cognitive models to the design of application user interfaces.
f. Apply social psychology in the design of a user interface
g. Use contextual, societal, cultural, and organizational factors in the design of a user interface.

ITE-UXD-05 Affective user experiences
Minimum instructional hours: 2 hours

Competencies:

a. Explain how a user develops an emotional reaction to or attachment to a product, service, or system.
b. Describe how a user's emotional reaction to an interface can interfere with product or service acceptance.
c. Describe how a user's emotional reaction to a product can advance product or service acceptance.

ITE-UXD-06 Human-centered evaluations
Minimum instructional hours: 3 hours

Competencies:

a. List three general principles used in the heuristic evaluation of a user interface design.
b. Classify usability performance and preference metrics: learning, task time, task completion, effectiveness, and user satisfaction.
c. Describe common usability guidelines and standards.
d. Explain two ways of measuring application usability employing a heuristic evaluation.
e. Document an existing system or product with storyboarding techniques.
f. Create an appropriate usability test plan.
g. Describe two ways to measure product usability from performance and preference metrics.

ITE-UXD-07 Assistive technologies and accessibility
Minimum instructional hours: 3 hours

Competencies:

a. Describe two main principles for universal design.
b. List three of the advantages and disadvantages of biometric access control.
c. Describe the symptoms of repetitive stress syndrome; list some of the approaches that can ameliorate the problem.
d. Employ accessibility guidelines and standards in the design of a user interface.
e. Design a user interface to effectively use accessibility features such as an automated narrator.
f. Describe a criterion for choosing a biometric access system for a given application.
g. Identify one assistive technology computer device for persons with visual, hearing, cognitive, or motor difficulties.
h. Describe a possible interface that allows a user with severe physical disabilities to use a website.

ITE-UXD-08 User advocacy
Minimum instructional hours: 1 hour

Competencies:

a. List the advantages and disadvantages for using a human-centered software development approach.
b. Analyze and model the user environment and context of use before designing a software application.
c. Analyze user groups and develop appropriate personas to represent them in design.
d. Select appropriate user tasks for an application under consideration.
e. Describe the effect of socialization on the effectiveness of an application interface.
f. Explain the importance of evaluating the impact of proposed system changes on the user experience.

A.2 Supplemental IT Domains

ITS-DSA Data Scalability and Analytics

[30 hours]

Domain Scope

1. Key technologies for collecting, cleaning, manipulating, storing, analyzing visualizing, and extracting useful information from large and diverse data sets
2. Instructional algorithms for analyzing large sets of structured and unstructured data
3. Challenges of large scale data analytics in different application domains

ITS-DSA Subdomains

ITS- DSA-01 History and overview
Minimum instructional hours: 1 hour

Competencies:

a. Discuss the emerging field of data science.
b. Identify two sources of large volumes of data.
c. Recognize challenges in analytics of very large volumes of data.
d. Describe how analytics can be used in major functional areas of an organization.

ITS-DSA-02 Foundations
Minimum instructional hours: 8 hours

Competencies:

a. Describe large-scale data challenges volume, variety, velocity and veracity.
b. Define two challenges of large scale data analytics in diverse sectors such as sensor networks, finance, retail, genomics and social media.
c. Compare two different data platforms that can be used for processing and generating large data sets.
d. Use statistical programming language such as R or Python.

ITS-DSA-03 Data Management
Minimum instructional hours: 4 hours

Competencies:

a. Discuss two common Extract Transform Load scenarios.
b. Apply data preprocessing techniques - data integration, data cleansing, data transformation and data reduction.
c. Discuss how to extract knowledge and insights from large and complex collections of digital data.
d. Use data mining software to perform data mining.

ITS-DSA-04 Methods, tools and techniques
Minimum instructional hours: 6 hours

Competencies:

a. Explain technical foundations of the commonly used data analysis methods.
b. Apply two appropriate data analysis methods to solve real-world problems.
c. Use tools such as RStudio, MapReduce/Hadoop and SAS.
d. Explain the results of data analysis to technical and management audience.
e. Describe the results of data analysis using visualization, social network analysis, and regression analysis.

ITS-DSA-05 Data governance
Minimum instructional hours: 5 hours

Competencies:

a. Identify the importance of data governance for managing large-scale data.
b. Identify two logical and physical access security controls to protect data.
c. Identify current social, ethical, legal and policy issues caused by the large scale data analytics.
d. Define data ethics.
e. List three regulatory compliance rules and regulations applicable to data management.

ITS-DSA-06 Application
Minimum instructional hours: 6 hours

Competencies:

a. Define a business problem as an analytics problem.
b. Describe how to best apply large-scale analytics methods and techniques in addressing strategic business problems.
c. Apply a data analytics lifecycle to a case study scenario.
d. Implement data-intensive computations on cluster and cloud infrastructures.
e. Examine the impact of large-scale data analytics on business performance using case studies.

ITS-ANE Applied Networks

[30 hours]

Domain Scope

1. Purpose and role of proprietary network protocols, and comparing proprietary networks with open standard protocols
2. Protocols and languages in network programming; socket-based network application programs design and implementations
3. Components of Voice over IP (VoIP) networks and protocols, and configurations of voice gateways for supporting calls using various signaling protocols
4. Scientific field routing and protocols in the internet, IPv6 and the internet protocol of the future
5. Basic mobile network architectures and protocols used in wireless communications

<u>ITS-ANE Subdomains</u>

ITS-ANE-01 Proprietary networks

Minimum instructional hours: 6 hours

Competencies:

a. Describe three proprietary network protocols.
b. Describe the advantages and disadvantages of building upon proprietary networks.
c. Compare proprietary network protocols versus open standard protocols.
d. Describe principal components and technologies the system network architecture (SNA), which is IBM's proprietary networking architecture.
e. Analyze proprietary network management schemes.
f. Design and maintain a proprietary network protocol.

ITS-ANE-02 Network programming

Minimum instructional hours: 5 hours

Competencies:

a. Describe the role of socket programming in communicating between systems.
b. Contrast the protocols and uses of TCP/IP sockets and datagram sockets.
c. Use various solutions to perform inter-process communications.
d. Demonstrate knowledge of protocols and languages used in web and multimedia delivery.
e. Demonstrate advanced knowledge of programming for network communications.
f. Write your own socket-based network application programs.
g. Describe three major technologies used in network communications.
h. Design, develop and test a socket program that communicates between two different services using both TCP/IP sockets and datagram sockets.
i. Design, develop and test a program that uses a messaging service to send asynchronous messages to another application across the network.

ITS-ANE-03 Routing protocols

Minimum instructional hours: 4 hours

Competencies:

a. Describe the meaning of a routing protocol.
b. Contrast an IPv4 subnet with an IPv6 subnet.
c. Explain the advantages of using an enhanced interior gateway routing protocol (EIGRP) over an interior gateway routing protocol (IGRP).
d. Contrast dynamic routing with static routing.
e. Illustrate how traffic is routed using a mobile IP.

ITS-ANE-04 Mobile networks

Minimum instructional hours: 4 hours

Competencies:

a. Use a basic mobile network architecture.
b. Analyze new developments in the field of mobile communications and mobile internet.
c. Assess new developments in the field of mobile communications and internet using principles, techniques and tools developed throughout the course.
d. Demonstrate an understanding of existing technologies for mobile internet and how they can be used, optimized, and enhanced for practical situations using concepts and techniques presented.
e. Describe three main characteristics of mobile IP and explain how it differs from IP with regard to mobility management and location management as well as performance.

f. Describe areas of interest that lie within mobile networks including multimedia, wireless, and mobile computing, and distributed computing.
g. Contrast between mobile networks of varying quality.
h. Describe the extension of client-server model to accommodate mobility and client cache management.
i. Explain two security issues related to mobile computing.
j. Describe performance issues related to mobile computing.

ITS-ANE-05 Wireless networks
Minimum instructional hours: 4 hours

Competencies:
a. Provide an overview of the history, evolution, and compatibility of wireless standards.
b. Identify two special problems related to wireless and mobile computing.
c. Contrast between wireless LANs and cellular networks.
d. Demonstrate two specific differences between physical networking and wireless networking.
e. Compare two different solutions for communications at each network layer.
f. Identify three protocols used in wireless communications.
g. Perform simulations of wireless networking.
h. Explain security issues related to wireless networks.
i. Describe performance issues related to wireless networks.

ITS-ANE-06 Storage area networks
Minimum instructional hours: 2 hours

Competencies:
a. Describe a storage area network (SAN).
b. Describe a network-attached storage (NAS).
c. Contrast advantages of SAN and NAS over direct-access storage (DAS).
d. Enumerate three benefits gained from using storage area networks.
e. Describe storage advantages of internet small computer systems interface (iSCSI) over small computer systems interface (SCSI).

ITS-ANE-07 Applications for networks
Minimum instructional hours: 5 hours

Competencies:
a. Describe a network application.
b. Distinguish between a network application and a network-based application.
c. Contrast peer-to-peer (P2P) architectures with client-server architectures.
d. Describe differences between instant messaging and email.
e. Explain the underlying architecture utilized for multi-user network games.
f. Contrast land-line telephone communication with internet communication.
g. Describe the challenges of real-time video conferencing.

ITS-IOT Internet of Things

[30 hours]

Domain Scope

1. Core knowledge and skills required to engage in the creative development and design of innovative IoT solutions
2. Trends and characteristics in IoT
3. Analysis of the challenges and applying adequate patterns for user-interaction in IoT
4. Impact of IoT in signal processing, data acquisition and wireless sensor networks
5. Relationships between IoT and intelligent information processing
6. General internet operations compared with internet of things operations

ITS-IOT Subdomains

ITS-IOT-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Define the meaning of internet of things and related concepts such as the web of things, industrial internet, pervasive computing, and smart systems.
b. Explain when IoT became part of an IT curriculum.
c. Describe the historical stages and growing evolution of the IoT concept.

ITS-IOT-02 IOT architecture

Minimum instructional hours: 4 hours

Competencies:

a. Describe of various IoT domains.
b. Define key components and architectural frameworks for the IoT.
c. Illustrate the challenges in defining the architecture for different IoT applications.

ITS-IOT-03 Sensor and actuator interfacing

Minimum instructional hours: 2 hours

Competencies:

a. Define two concepts necessary to understand and to develop elements for multimedia systems.
b. Illustrate the impact of signal processing concepts on applications in speech and in basic sound generation.
c. Categories of signal processing: analog signal processing, continuous-time signal processing, discrete-time signal processing and digital signal processing.
d. Describe three typical devices related to signal processing (e.g., filters, samplers, signal compressors, digital signal processors).
e. Illustrate how to interface to sensors and actuators.

ITS-IOT-04 Data acquisition

Minimum instructional hours: 3 hours

Competencies:

a. Define data acquisition and signal conditioning.
b. Illustrate the impact of IoT on multiplexing and sampling theory.
c. Explain the electrical, temperature and strain measurements.
d. Describe how to reduce and isolate noise.
e. Define Machine-to-Machine (M2M) communication (a major component of the IoT portfolio of technologies).
f. Discuss the security issue and challenges of collaborative data acquisition in IoT.

ITS-IOT-05 Wireless sensor networks

Minimum instructional hours: 4 hours

Competencies:

a. Define the historical of Wireless sensor networks (WSNs).
b. Wireless sensor networks architectures, protocols, and algorithms.
c. Stack-based approaches and topology-based approaches for the integration of wireless sensor networks.
d. Identify two applications in various domains, such as health-care, assisted and enhanced-living scenarios, industrial and production monitoring, control networks, and many other fields.

ITS-IOT-06 Ad-hoc networks
Minimum instructional hours: 2 hours

Competencies:

a. Define ad hoc networks, design and implementation issues, and available solutions.
b. Identify two different routing techniques (proactive routing, reactive routing, hybrid routing and position-based routing).
c. Describe clustering mechanisms in ad hoc networks.
d. Analyze the quality-of-service and scalability issues in the context of ad-hoc networks.
e. List three applications of mobile ad hoc networks (MANET), such as vehicular ad hoc networks (VANETs), smart phone ad hoc networks (SPANs) and internet based mobile ad-hoc networks (iMANETs).

ITS-IOT-07 Automatic control
Minimum instructional hours: 4 hours

Competencies:

a. Define the elements of classical control theory as applied to the control of aircraft and spacecraft.
b. Describe the concept of feedback and its properties.
c. Functions of automatic control (measurement, comparison, computation and correction).
d. List two common elements of automatic control (measurement, error detection and final control element) in systems.
e. Illustrate a working knowledge of the basic linear design techniques, in particular as applied to spacecraft and aircraft.
f. Applications in various domains based on automatic control systems.

ITS-IOT-08 Intelligent information processing
Minimum instructional hours: 4 hours

Competencies:

a. Define the intelligent information processing and their applications in industry.
b. Identify intelligent information discovery, retrieval and mining on IoT.
c. Explain knowledge expression and context-aware systems.
d. Define sensor selection, information mashup and integration.
e. Explain information quality management in sensor networks.
f. Define real-time scene reconstruction, information visualization.

ITS-IOT-09 IoT application and design
Minimum instructional hours: 6 hours

Competencies:

a. Describe the relevance applications for IoT in smart cities, smart environment, eHealth, and in other areas.
b. Illustrate the impact of IoT on existing business models and business use cases.
c. Explain the IoT in conjunction with big data, applications, and mobility.
d. Define the components required for the IoT.
e. Describe two tools that are using in designing IoT.
f. List a set of capabilities that a technology specialist can dial up or down depending on tradeoffs and decisions made in IoT design.
g. Define smart manufacturing, such as flow optimization, real time inventory, asset tracking, employee safety.
h. Identify wearables, such as entertainment, fitness, smart watch and tracking.
i. Explain IoT design considerations: domain, requirement, cost, remote, network.

ITS-MAP Mobile Application

[25 hours]

Domain Scope

1. Mobile application technologies with experiences to create mobile applications
2. Mobile architectures, including iOS and Android
3. Creation of mobile applications on different platforms
4. Evaluation and performance improvement of mobile applications
5. Designing friendly interfaces for mobile applications

ITS-MAP Subdomains

ITS-MAP-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Explain the history of mobile development and mobile applications.
b. Describe the global scope of the processes of implementing a mobile application.
c. Describe two development environments for mobile applications.

ITS-MAP-02 Architectures

Minimum instructional hours: 2 hours

Competencies:

a. Describe the global scope of architectures for different mobile systems.
b. Explain the UI elements and the concepts glossary for mobile phones.
c. Explain each element of the mobile architecture framework.

ITS-MAP-03 Multiplatform mobile application development

Minimum instructional hours: 5 hours

Competencies:

a. Contrast iOS, Android, Windows Phone, BlackBerry, and Symbian platforms.
b. Design and implement a simple mobile application for a given mobile platform.
c. Run a mobile web application within a browser.
d. Explain hybrid web applications through an application programming interface (API).
e. Describe a platform-independent interpreted web application.
f. Explain the importance of applications generated by cross-compilation.

ITS-MAP-04 Servers and notifications

Minimum instructional hours: 2 hours

Competencies:

a. Describe protocol suites.
b. Explain the mechanism for notification delivery.
c. Provide techniques for server-side programming.
d. Design and implement a server side application.

ITS-MAP-05 Performance issues

Minimum instructional hours: 3 hours

Competencies:

a. Describe two metrics and methods to evaluate performance of mobile applications.
b. Evaluate the performance of a mobile application and give its result.
c. Describe two ways to improve mobile performance.

ITS-MAP-06 Views and gestures

Minimum instructional hours: 3 hours

Competencies:

a. Describe each element about views.
b. Explain text and typesetting units.
c. Explain two ways to improve picture presentation.
d. Provide three methods to improve gesture definition and its application.

ITS-MAP-07 Interface implementations

Minimum instructional hours: 4 hours

Competencies:

a. Design a friendly interface framework.
b. Explain two ways to improve user experience through color adjustment and other resources.
c. Identify two modern UI design tools.
d. Contrast SDKs to access device features.
e. Provide three ways to improve cross-platform accommodation and support.

ITS-MAP-08 Camera, state, and documents interaction

Minimum instructional hours: 3 hours

Competencies:

a. Describe two concepts of basic service and functions.
b. Manipulate streams from camera and microphones.
c. Describe two techniques for implementing applications about mobile states.
d. Explain the usefulness of document interaction control.

ITS-MAP-09 2D graphic and animation

Minimum instructional hours: 2 hours

Competencies:

a. Identify two basic concepts of 2D graphic and animation.
b. Draw graphics on different mobile platforms.
c. Implement a dynamic graphic transformation for animation.
d. Implement 2D graphics and animation on two mobile devices using different operating systems.

ITS-SDM Software Development and Management

[20 hours]

Domain Scope

1. Software process models and software project management
2. Software development phases: requirements and analysis, design and construction, testing, deployment, operations, and maintenance
3. Modern software development and management platforms, tools, and services

ITS-SDM Subdomains

ITS-SDM-01 Process models and activities

Minimum instructional hours: 5 hours

Competencies:

a. Describe the software development process including analysis and design.
b. Differentiate among phases in software development.
c. Compare software process models based on size, functional requirements, and design qualities of the software system and team and infrastructure resources.
d. Assess development effort and participate in process improvement by tracking commitments and managing project quality.

ITS-SDM-02 Platform-based software development

Minimum instructional hours: 2 hours

Competencies:

a. Describe how modern user experiences beyond the browser influence software development for mobile devices, touch screens, gesture and voice-controlled interactions, 3D immersion or virtual reality, sensor industrial networks, and game platforms.
b. Develop a software application using library and other service interfaces (e.g., APIs) specific to the user 's particular platform.
c. Explain the differences among platform-specific development and general purpose programming.
d. Describe the constraints that particular platforms impose on development.

ITS-SDM-03 Tools and services

Minimum instructional hours: 4 hours

Competencies:

a. Describe two modern tools and services that improve efficiency and effectiveness of developers working in teams on systems with various challenges (e.g., size, constrained by time or resources, legacy code).
b. Select and use two appropriate tools for requirements tracking, design modeling, implementation, build automation, and bug tracking.
c. Conduct inspections, code reviews, audits and indicate the results of the evaluation.
d. Describe the use of version control to manage software configuration and release management.

ITS-SDM-04 Management

Minimum instructional hours: 5 hours

Competencies:

a. Describe the importance of project management as it relates to software development.
b. Engage in team building and team management in a software development project.
c. Plan, monitor, and track progresses for a project activity using project management tools.
d. Assess, mitigate, and manage risks that affect decisions in the software development process.
e. Use project metrics to monitor a project's progress.

ITS-SDM-05 Deployment, operations, and maintenance

Minimum instructional hours: 4 hours

Competencies:

a. Use two appropriate tools to deploy, operate, and maintain a software system.
b. Practice version tracking, automated building, and release of software systems.
c. Explain the difference between pre-production and production software operation environments.
d. Extend the software process with phases that are more relevant in IT: deployment, operations, and maintainability.

ITS-SRE Social Responsibility

[20 hours]

Domain Scope

1. Historical, social, governmental and environmental context of computing
2. Importance of team dynamics to an organizations' success
3. Governmental regulations address global challenges
4. Professional contexts of information technology and the role of risk management
5. Energy standards and regulations

ITS-SRE Subdomains

ITS-SRE-01 Social Context of Computing

Minimum instructional hours: 4 hours

Competencies:

a. Explain the importance of the social context of IT and adherence to ethical codes of conduct.
b. Explain the importance of green computing strategies.
c. Identify two historical, social, professional, ethical and legal aspects of e-computing.
d. Identification of three ways teamwork integrates throughout IT and supports an organization.
e. Contrast how computing alters the modes of interaction between persons.

ITS-SRE-02 Goals, plans, tasks, deadlines and risks

Minimum instructional hours: 4 hours

Competencies:

a. Describe two computer IT projects where teamwork approaches are important.
b. Explore two ways in which industry approaches teamwork toward a common goal.
c. Describe the skill sets necessary to function effectively in a team environment.
d. Implement three planning team goals.

ITS-SRE-03 Government role and regulations

Minimum instructional hours: 3 hours

Competencies:

a. Discuss the role of government regulations on organizations as well as on a global scale.
b. Define the role of the government and how it affects software projects.
c. Analyze the different national approaches to green computing policy creation and implementation.
d. Explain the importance of regulation in the control of efficient waste reduction and recycling.

ITS-SRE-04 Global challenges and approaches

Minimum instructional hours: 3 hours

Competencies:

a. List IT approaches to reduce energy consumption such as thin client solutions, server virtualization, telecommuting, hibernation, dynamic voltage.
b. Describe the employment of environmental computing practices in the life cycle of IT applications and system design.
c. Classify organizational green computing performance metrics, recycling practices, energy use and e-waste reduction.

ITS-SRE-05 Risk management

Minimum instructional hours: 3 hours

Competencies:

a. Identify the aspects of a business that may be impacted by a security breach or interruption of operation.
b. Quantify the financial losses associated with potential security breaches and interruption of operations.
c. Identify and describe steps to assess risks associated with security specified by the National Institute of Standards and Technology (NIST).
d. Describe the costs associated with actions that can be taken to mitigate security risks.

ITS-SRE-06 Energy standards utilities
Minimum instructional hours: 3 hours

Competencies:

a. List two examples of sensor and monitoring software used to track energy use.
b. Describe two techniques for the use of renewable energy sources (i.e. solar and wind power).
c. Explain how incentives for green computing in the work place will enhance their use.
d. Describe capital investment projects needed to continue stable energy delivery.

ITS-SRE-06 Energy standards
Minimum instructional hours: 2 hours

Competencies:

a. Describe common energy saving guidelines and standards (e.g., Energy Star international standard).
b. Match descriptions of industry standards with the industry standard names. (e.g., advanced configuration and power (ACP) interface design and manufacturing of computer components for power savings).
c. List computer hazardous materials and describe management techniques.

ITS-VSS Virtual Systems and Services

[30 hours]

Domain Scope

1. Virtualization and its related open source components
2. Deployment skills to build virtualization and clustered solutions
3. Networked storage for virtualization infrastructure needs

ITS-VSS Subdomains

ITS-VSS-01 History and overview

Minimum instructional hours: 1 hour

Competencies:

a. Define virtualization.
b. Define virtual machine.
c. Define host machine.
d. Explain the role of the hypervisor.
e. Describe the different configurations of a hypervisor on the host machine.

ITS-VSS-02 Implementation of virtualization

Minimum instructional hours: 5 hours

Competencies:

a. Describe two types of situations where virtualization is an appropriate solution.
b. Describe the advantages and disadvantages of virtualization in different application areas.
c. Contrast virtualization with clustering applications.

ITS-VSS-03 User Platform virtualization

Minimum instructional hours: 3 hours

Competencies:

a. Define user platform (i.e., desktops and devices) virtualization.
b. Describe the operational advantages and disadvantages of a virtualized device.
c. Install a virtual machine on a host machine.
d. Install and configure different operating systems on a virtual machine.

ITS-VSS-04 Server virtualization

Minimum instructional hours: 3 hours

Competencies:

a. Define server virtualization.
b. Describe the operational advantages and disadvantages of a virtualized server.
c. Install a virtual machine on a host server.
d. Install and configure different server systems on a virtual computer.
e. Evaluate the performance of virtualized servers against industry benchmarks.

ITS-VSS-05 Network virtualization

Minimum instructional hours: 5 hours

Competencies:

a. Describe the differences between a real and virtualized networks.
b. Describe the operational advantages and disadvantages of a virtualized network.
c. Evaluate different network management strategies using a virtual network.

ITS-VSS-06 Cluster design and administration

Minimum instructional hours: 5 hours

Competencies:

a. Contrast two different server cluster designs.
b. Describe tools and techniques used for cluster administration.
c. Design, install and configure a cluster in the lab.
d. Adjust cluster configurations to accomplish different operational objectives.

ITS-VSS-07 Software clustering application

Minimum instructional hours: 5 hours

Competencies:

a. Explain the role of clustering software.
b. Contrast high availability vs high performance clustering.
c. Research and evaluate the suitability of cluster software and middleware tools in different operational contexts.
d. Describe the application cluster concepts such as load balancing, failover, and node monitoring.

ITS-VSS-08 Storage

Minimum instructional hours: 3 hours

Competencies:

a. Describe the different storage environments.
b. Describe the operational advantages and disadvantages of the storage alternatives.
c. Install and configure a storage environment and file system.
d. Evaluate the performance of storage and file systems against industry benchmarks.
e. Explain a tiered storage environment.

ITS-CCO Cloud Computing

[30 hours]

Domain Scope

1. Concepts of cloud computing as a new computing paradigm
2. Cloud computing fundamentals, security principles and applications
3. Theoretical, technical and commercial aspects of cloud computing
4. Architecture and cloud software development
5. Case studies and existing cloud-based infrastructure

ITS-CCO Subdomains

ITS-CCO-01 History and overview
Minimum instructional hours: 1 hour

Competencies:

a. Define the meaning of cloud computing.
b. Indicate when cloud computing first became a service delivery model.
c. Contrast the different categories of cloud computing services (i.e. SaaS, IaaS, PaaS, BusinessProcess-BPaaS).
d. Describe two reasons for making cloud computing an essential part of information technology.

ITS-CCO-02 Concepts and fundamentals
Minimum instructional hours: 6 hours

Competencies:

a. Explain the conceptual terms of cloud computing.
b. Categorize the different service types within cloud service delivery.
c. Compare the responsibilities of service providers vs. cloud service consumers/customers.
d. List two privacy legislation examples as they relate to cloud computing.
e. Contrast private sector and public sector requirements.
f. Classify the business drivers for using cloud services including risk/benefit assessment (i.e. cloud first).

ITS-CCO-03 Security and data considerations
Minimum instructional hours: 6 hours

Competencies:

a. Explain how contract negotiation relates to cloud computing (e.g., the right to audit).
b. Explain why organizational accountability for data and system security still exists in a cloud service, delivery model.
c. Describe two scenarios in which a breach of security may occur.
d. Describe what safe guards and security models should be in place to reduce business risk (i.e., consent/notice requirements, data classification).
e. List three potential security tools and design techniques used to ensure security is built-in to cloud services.

ITS-CCO-04 Using cloud computing applications
Minimum instructional hours: 5 hours

Competencies:

a. Describe two different types of cloud applications.
b. Describe the differences between an internal application and a cloud application.
c. Match descriptions of cloud service types with cloud service names.
d. Identify two samples of risk/ benefit assessments when selecting applications.
e. List three examples of application characteristics that will not, or should not, run in the cloud.

ITS-CCO-05 Architecture
Minimum instructional hours: 4 hours

Competencies:

a. List three general architecture principles of cloud computing service delivery.
b. Contrast cloud architectures to outsourcing (i.e. hosted) and shared services models.
c. Describe common change control guidelines and standards as they relate to cloud services.
d. Explain two ways of measuring cloud service performance and the importance of service level agreements.
e. Describe the challenges of ‘big data’ analytics in the cloud.
f. Contract singe cloud vs multiple cloud deployment models.

ITS-CCO-06 Development in the cloud
Minimum instructional hours: 4 hours

Competencies:
a. List three of the advantages and disadvantages of cloud applications.
b. Describe the differences in developing systems in cloud environments as compared to traditional environments.
c. Identify on-demand, self-service design requirements.
d. Contrast the use of synchronous vs. asynchronous transactions.
e. Describe a criterion for choosing coupled or de-coupled system integration.
f. Describe a possible interface for a cloud application to be used on a smartphone.

ITS-CCO-07 Servers and platforms
Minimum instructional hours: 4 hours

Competencies:
a. Describe the infrastructure difference between public cloud computing, private cloud computing and hybrid models.
b. Describe of how virtualization is a driving principle behind cloud computing.
c. Illustrate how rapid elasticity is a characteristic of cloud computing infrastructure.
d. List the desirable and undesirable characteristics of cloud data management.
e. Illustrate how emerging technologies could change the design of a cloud services (i.e., IoT).

ITS-CEC Cybersecurity Emerging Challenges

[30 hours]

Domain Scope

1. Forensics as related to networks, data storage and mobile devices
2. Security techniques and metrics associated with hardware and software elements
3. Skills needed for administering, securing, and implementing information systems and networks
4. Emerging areas that increase risk

ITS-CEC Subdomains

ITS-CEC-01 Case studies and lessons learned
Minimum instructional hours: 2 hours

Competencies:

a. Discuss the deployment of a new technology and its impact on cybersecurity.
b. Discuss the role of law enforcement in a criminal cybersecurity investigation with reference to a court-filed FBI complaint.
c. Summarize a cybersecurity event that had global reach, such as the DigiNotar incident or the SSL Heartbleed vulnerability.
d. Identify two sources of case studies and lessons learned.

ITS-CEC-02 Network forensics
Minimum instructional hours: 4 hours

Competencies:

a. Define network forensics.
b. Identify information that is visible over a network.
c. Perform a network inventory.
d. Distinguish active and passive approaches to network forensics.
e. Perform a man-in-the-middle attack to reveal the content of an encrypted network communication.
f. Employ surveillance mechanisms to discover network intrusion.

ITS-CEC-03 Stored data forensics
Minimum instructional hours: 4 hours

Competencies:

a. Identify two locations where data may be stored in a complex system.
b. Apply two criminal investigative techniques to basic computer forensic investigations.
c. Define two digital evidence for presentation in court.
d. Identify the presence of contraband information on a desktop computer.
e. Prepare an inventory of the files on a desktop computer.
f. Reconstruct a timeline from information on a device being analyzed.
g. Perform a logical file extraction.
h. Perform a physical extraction of evidence.
i. Extract a memory dump from a running computer.
j. Compare commercial and open source forensic tools.

ITS-CEC-04 Mobile forensics
Minimum instructional hours: 2 hours

Competencies:

a. Prepare an inventory of the files on a mobile device (e.g., a phone, tablet, or embedded system).
b. Prepare a list of the applications and remote services used by a mobile device.
c. Identify the major operating systems used in mobile devices and discuss their differences from the vantage point of a forensics investigation.
d. Identify the difference between unlocking and “rooting” mobile devices.
e. Discuss three strategies for detecting and revealing encrypted contents.

ITS-CEC-05 Cloud security
Minimum instructional hours: 2 hours

Competencies:

a. Identify the different security issues in platform as a service, infrastructure as a service, and software as a service.
b. Explain the FedRAMP requirements.
c. Evaluate the security benefits and risks of cloud storage systems.
d. Discuss two authentication strategies for users of cloud systems.
e. Discuss two forensic options for analyzing cloud-based systems.
f. Discuss two auditing and recovery options for cloud servers.

ITS-CEC-06 Security metrics
Minimum instructional hours: 2 hours

Competencies:

a. Identify two requirements of security metrics.
b. Identify data that supports to creation of metrics.
c. Identify a network resource that can have its security measured.
d. Explain the role of continuous monitoring in a security practice.
e. Identify two security metrics used to detect compliance and risk issues.

ITS-CEC-07 Malware analysis
Minimum instructional hours: 3 hours

Competencies:

a. Identify three tools to perform malware analysis.
b. Distinguish static and dynamic analysis.
c. Discuss proper laboratory procedures for handling malware.
d. Identify two malware repositories.
e. Perform static analysis on malware to determine some of the actions that it can perform.
f. Perform dynamic analysis on malware to determine network resources that it utilizes.
g. Determine whether a specific malware detector would identify a malware sample.

ITS-CEC-08 Supply chain and software assurance
Minimum instructional hours: 2 hours

Competencies:

a. Describe a hardware supply chain.
b. Describe a software supply chain.
c. For each stage in the lifecycle of a product, describe what security considerations should be evaluated.
d. Identify two techniques for secure software development including the use of safe language, static analysis of software, and dynamic software testing.
e. Identify two common defects, bugs, and logic flaws in software.

ITS-CEC-09 Personnel and human security
Minimum instructional hours: 2 hours

Competencies:

a. Describe two ways in which an insider can intentionally and unintentionally reduce or affect an organization’s security posture.
b. Discuss the use and limits of background checks to in screening an organization’s employees.
c. Explain three concepts of phishing and spear phishing, and how to recognize them.
d. Explain two benefits and risks of a ‘bring your own device’ (BYOD) program.
e. Explain potential impact of browsing “risky” websites such as pornographic websites and hacker forums, from home and at work.
f. Identify two ways that social media increases the risk of social engineering attacks.

ITS-CEC-10 Social dimensions
Minimum instructional hours: 2 hours

Competencies:

a. Discuss the trade-off between utility and risk of cloud computing, file sharing, and peer-to-peer services.
b. Discuss the impact of IT systems on privacy.
c. Identify the tension between personal privacy, accountability, and deterrence of cybersecurity events.
d. Identify two risks to data confidentiality, integrity, and availability that might result from various crowdsourcing techniques such as big data mining.

ITS-CEC-11 Security implementations

Minimum instructional hours: 2 hours

Competencies:

a. Discuss the options for enterprise malware detection.
b. Contrast the effectiveness and costs of malware detection with application whitelisting.
c. Identify the limitation of penetration testing.
d. Contrast the security implications of homogeneous and heterogeneous networks.
e. Model the cost of defense, recovery and remediation for a small business and a large-scale enterprise.
f. Define “security containers” and identify their limitations and usability failings with respect to mobile devices.

ITS-CEC-12 Cyber-physical systems and the IoT

Minimum instructional hours: 3 hours

Competencies:

a. Discuss why the terms CPS and IoT are often used interchangeably and identify definitions that indicate the differences between them.
b. Identify the protocols and networks typically used to connect CPS and IoT devices to networks.
c. Identify security mechanisms used to address IT challenges that may not be viable in the world of CPS or IoT.
d. Design, create, and deploy a IoT device using open source and low cost computing platforms.
e. Discuss the challenges of the handling and storage of data delivered by IoT devices with a specific focus on security & privacy

Appendix B:
Information Technology Curricula Samples

This appendix to the *Computing Curricula – Information Technology (IT2017)* report contains several sample curricula that illustrate possible curricula implementations of degree programs that satisfy the required specifications of the IT curricular framework detailed in the main body of this report. These samples illustrate how undergraduate programs of different flavors and of different characteristics could implement these recommendations to suit different institutional requirements and resource constraints. Hence, they serve a wide variety of educational goals and student needs. None of these samples is prescriptive.

The following table summarizes the sample curricula in this appendix. This table serves as a guide to identifying sample curricula that are most relevant to particular geographic and institutional needs as well as program priorities.

Curriculum	Country or Region
A	Kingdom of Saudi Arabia
B	United States of America

B.1 Format and Conventions

All sample curricula in this appendix use a common format with five logical components. These are:

1. A set of educational objectives for the program of study and an explanation of any assumed institutional, college, department, or resource constraints
2. A summary of degree requirements, in tabular form, to indicate the curricular content in its entirety
3. A sample schedule that a typical student might follow
4. A map showing coverage of the information technology curricular framework by courses in the curriculum
5. A set of brief course descriptions for those courses in the computing, mathematics, and science components of the curriculum

B.1.1 Course Hour Conventions

To clarify the identification of courses, levels, and implementations, course numbers reflect ways that identify the curriculum in which it appears and the level at which it appears in the program. Thus, a course numbered MTH$_X$100 is a course in curriculum X commonly taught in the first year (at the freshman level). Likewise, PHY$_X$200 is a course commonly taught in the second year (at the sophomore level); IT$_X$300 is a course commonly taught in the third year (at the junior level); and course IT$_X$400 is commonly taught in the fourth year (at the senior level).

To provide ease of comparison, all curricula implementations appear as a set of courses designed for a system in which a semester provides 14 weeks of lecture and laboratory. Typically, there is the equivalent of one week for examinations, vacations, and reading periods. Hence, we have 15 weeks of instruction delivery and testing. For simplicity, we specify lecture and lab times in "hours", where one "hour" of lecture or lab is typically 50 minutes in duration.

We assign each course a number of semester credit hours, according to the number and types of formal activities within a given week. These are determined as follows.

- Lecture hours: presentation of material in a classroom setting
    - 1 credit hour = One, 1-hour lecture per week for 15 weeks
- Laboratory hours: formal experimentation in a laboratory setting
    - 1 credit hour = One, 3-hour laboratory session per week for 15 weeks

The following are examples of ways to calculate credits for lectures and laboratories where the word "hour" is a 50-minute time segment.

- *3-credit lecture course*:
  3 lecture hours per week for 14 weeks = 42 lecture hours (plus one week for examinations)
- *1-credit laboratory course*:
  Either one 2-hour laboratory session per week for 14 weeks = 28 lab hours
  or one 3-hour laboratory session per week for 14 weeks = 42 lab hours
- *3-credit course with two lectures and a lab session each week*:
  2 lecture hours per week for 14 weeks = 28 lecture hours (plus one week for examinations)
  One 3-hour lab per week for 14 weeks = 42 lab hours
- *3-credit project design course*:
  1 classroom meeting per week for 14 weeks = 14 lecture hours (plus one week for examinations)
  2 credits of laboratory = 6 hours of laboratory per week for 14 weeks = 84 lab hours

B.1.2 Mapping of the information technology curricular framework to a sample curriculum

Each sample curriculum contains a table that maps the information technology curricular framework to the sample curriculum. The table rows contain course numbers with IT domains as column headers. If an entry in a row is non-empty, then it contains one or more of the numbered subdomains from the domain covered in that course. For example, the entry 3, 4, 6-10 under the GPP domain indicates that this course covers subdomains 3, 4, 6, 7, 8, 9, and 10 from the ITE-GPP domain. Note that:

- A course may have subdomains from one IT domain, or it may have subdomains from multiple IT domains.
- The same IT subdomain may appear in multiple courses. For example, a two course sequence in software fundamentals may both contain the ITE-SWF subdomain '1' as both courses may cover history, but from different perspectives.

The bottom two rows, labeled *Essential Units* and *Supplementary Units,* list the subdomains from each domain covered by this sample curriculum. Since all of the sample curricula have complete domain core coverage, the row labeled *Essential Units* contains all the subdomains from the IT domains. The row labeled *Supplementary Units* may contain non-empty entries, which list the supplementary subdomains covered in those domains. The sample curricula do not cover all of the supplementary domains and the coverage shown does not convey a priority or recommended coverage.

B.1.3 Course descriptions

The provided course descriptions are what might typically appear in a course catalog. Because of their length, the topics listed in these short descriptions are not an exhaustive list of topics taught in those courses. A list of the IT domains and subdomains covered by these courses augment these descriptions. For courses that include laboratory hours, these descriptions do not include details on the laboratory experience. The body of this report describes expectations for the overall laboratory experience, including teamwork, data collection and analysis, and other skills.

B.2 Preparation to Enter the Profession

The sample curricula in this appendix have as a major goal the preparation of graduates for entry into the information technology field. There are many ways of building an undergraduate curriculum whose graduates are well-educated information technologists. To illustrate this point, these programs differ in their emphasis and in the institutional constraints. For example, many programs include a first-year course to introduce students to the discipline, provide hands-on IT experiences, and engage the students in the field. The absence of such a course in any of the example curricula is not a judgment on the value of such courses.

The IT2017 task group designed these curricula to ensure appropriate coverage of essential domains of the computer engineering BOK as defined in this report. However, as also discussed in the main report, there are many other elements to creating a program that will effectively prepare graduates for professional practice such as system management and laboratory experience, oral and written communication, and usage of modern IT tools. Accordingly, professional accreditation addresses more than just curriculum, and readers interested in accreditation should consult the relevant criteria from their accrediting agency for complete accreditation criteria.

In addition, each IT program may have educational goals that are unique to that program and not directly reflected in the IT curricular framework and curriculum models presented in this report. It is the responsibility of each program to ensure that its students achieve each learning outcome in support of the educational goals of the program.

B.3 Curricula Commonalities

Students desiring to study the application of computers and networking will find information technology to be a rewarding experience. Study is intensive and students desiring to develop proficiency in the subfields of information technology such as the internet of things or cloud computing, will find information technology a pleasant challenge. Applied skills will enable students to analyze, design, and test IT processes. Each sample curriculum leads to a bachelor's degree in information technology and provides a balanced treatment of hardware and software principles.

The common requirements spread widely across a range of courses and allow revisiting the subject matter with spiral learning taking place. Each curriculum contains sufficient flexibility to support various areas of specialization. Each program structure allows a broadly based course of study and provides selection from among many professional electives. A combination of theory, practice, application, and attitudes accompany the construction of each course.

The goal of each program is to prepare students for a professional career in information technology by establishing a foundation for lifelong learning and development. It also provides a platform for further work leading to graduate studies in information technology, as well as careers in fields such as business, law, medicine, management and others. Students develop technical skills progressively, beginning with their first courses and then apply their accumulating knowledge to practical problems throughout the curriculum. The thorough preparation afforded by the information technology curriculum includes the broad education necessary to understand the effect of IT solutions in a global and societal context. Graduates of each program should be well prepared for professional employment or advanced studies. They should understand the various areas of information technology and they should be able to apply their acquired knowledge and skills to multiple areas of information technology.

B.4 Curriculum A: Typical IT Curriculum – Saudi Arabia

Information Technology Program
Administered by an Information Technology Department in Saudi Arabia

B.4.1 Program Goals and Features

This program leads to a bachelor's degree in information technology, as might be offered by a traditional information technology (IT) department. A computer science department offers foundation courses in computer science such as programming; the IT department teaches the remaining courses.

B.4.2 Summary of Requirements

This program of study contains 6 required computer science (CS) courses (22 credits) and 17 required information technology (IT) courses (51 credits). Flexibility is provided by the four information technology elective courses (12 credits), which can be chosen to cover the chosen supplemental IT2017 domains according to the goals of the program. The capstone experience occurs over two courses in the senior year, allowing for a substantial and complete practical experience. Students are required to join an IT center as a full time for at least 8 weeks to complete 280 hours to pass the practical training course. This curriculum requires 44 courses, with credit hours distributed as follows.

Requirement Type	No. of Course	Courses	Credit Hours
University Requirements	6	CUL101, 102, 103, 104	8
		ARB 104, 201	4
		Total Area Credit Hours	**12**
Department Requirements (General)	6	COM 207	2
		ENG 140, 190, 208	9
		ECO 100	2
		BUS 100	3
		Total Area Credit Hours	**16**
Department Requirements (Math & Science)	5	MATH 113, 114, 227	12
		STA 111	3
		PH 103	3
		Total Area Credit Hours	**18**
Department Requirements (Filed Specific)	27	CS_A 104, 106, 220	10
		CS_A 140, 141, 242	12
		IT_A 280 300, 301, 310, 315, 320, 331, 340, 360, 390	34
		IT_A 410, 412, 420, 490, 491, 492, 493	17
		IT Electives Courses	12
		Total Area Credit Hours	**85**
Total Credit Hours	**44**	*Total Credit Hours*	**131**

B.4.3 Four-Year Model for Curriculum A

IT: Offered in an information technology department
CS: Offered in a computer science department

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
CS_A 104	Discrete Structures	3	CS_A 106	Digital Logic	3
CS_A 140	Computer Programming 1	4	CS_A 141	Computer Programming 2	4
MATH 113	Differential Calculus	4	IT_A 280	IT Fundamentals	3
PH 103	General Physics & Lab	3	MATH 114	Integral Calculus	4
ENG 140	English Language 1	3	ENG 190	English Language 2	3
	Total Semester Credit Hours	**17**		*Total Semester Credit Hours*	**17**
Semester 3			**Semester 4**		
CS_A 220	Computer Organization	4	IT_A 360	Operating Systems	4
CS_A 242	Data Structures	4	IT_A 320	Introduction to Databases	3
IT_A 300	Human-Computer Interaction	3	IT_A 315	Technical Support	3
IT_A 301	Project Management	4	STA 111	Introduction to Probability & Statistics	3
MATH 227	Linear Algebra and Differential Equations	4	ENG 208	Technical Writing	3
			CUL 101	Islamic Culture 1	2
	Total Semester Credit Hours	**19**		*Total Semester Credit Hours*	**18**
Semester 5			**Semester 6**		
IT_A 340	Computer Networks	4	IT_A 420	Database Administration DBMS	3
IT_A 310	Cybersecurity Fundamentals	4	IT_A 410	IT Security and Risk Management	3
IT_A 390	Web Systems	3	IT_A 490	Learning & Thinking & Research	1
ARB 201	Expository Writing	2	IT_A xxx	IT Elective 1	3
COM 207	Communication Skills	2	ECO 100	Principles of Economics	2
CUL 102	Islamic Culture 2	2	CUL 103	Islamic Culture 3	2
			ARB 104	Language Skills	2
	Total Semester Credit Hours	**17**		*Total Semester Credit Hours*	**16**
Summer Semester					
IT_A 491	Practical Training	1			
	Total Semester Credit Hours	**1**			
Semester 7			**Semester 8**		
IT_A 331	Fundamentals of n-Tier Architectures	3	IT_A 493	Senior Project in Information Technology 2	4
IT_A 412	IT Governance	3	IT_A xxx	IT Elective 3	3
IT_A 492	Senior Project in Information Technology 1	2	IT_A xxx	IT Elective 4	3
IT_A xxx	IT Elective 2	3	BUS 100	Introduction to Business Administration	3
CUL 104	Islamic Culture 4	2			
	Total Semester Credit Hours	**13**		*Total Semester Credit Hours*	**13**

B.4.4 Mapping of Information Technology Curricular Framework to Curriculum A

Refer to section B.1.2 for an explanation of this table.

Essential Domains / ***Courses***	**CSP**	**GPP**	**IMA**	**IST**	**NET**	**PET**	**SAM**	**SIA**	**SWF**	**UXD**	**WMS**
CS_A 104											
CS_A 106											
CS_A 140									1-4		
CS_A 141									7		
CS_A 220											
CS_A 242									5-6		
IT_A 280	1	1	1	1	1	1	1	1		1	1
IT_A 300										2-8	
IT_A 301								2-6			
IT_A 310	2-7										
IT_A 315							2-6				
IT_A 320			2-4								
IT_A 331				2-6							
IT_A 340					2-7						
IT_A 360						2-5					
IT_A 390											2-7
IT_A 410	8-14										
IT_A 412		2-7									
IT_A 420			5-7								
IT_A 490		6-10									
IT_A 491		8-11									
IT_A 492		3,4, 6-10									
IT_A 493		12									
Subdomains Covered	**1-14**	**1-12**	**1-7**	**1-6**	**1-7**	**1-5**	**1-6**	**1-6**	**1-7**	**1-8**	**1-7**
Minimum Essential Hours	**40**	**25**	**40**	**20**	**35**	**15**	**20**	**20**	**30**	**20**	**25**

B.4.5 Curriculum A – Course Summaries

CS_A1 104: Discrete Structures
This course will introduce the student to a body of mathematical concepts essential for the mastery of some of the higher-level computer science courses. Topics include: Set theory, Functions and relations, Propositional and predicate logic, Proof techniques, Recursive Algorithms, Elementary combinatorics and Counting methods, Graph theory, and Discrete probability.
Prerequisites: None
Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITM-DSC 1-12

CS_A 106: Logic Design
This course focuses on the fundamental constructs and concepts underlying computer hardware and software which includes: number systems, binary arithmetic, codes, Boolean algebra, gates, Boolean expressions, Boolean switching function synthesis, iterative arrays, sequential machines, state minimization, flip/flops, sequential circuits, simple processors.
Prerequisites: CS_A104
Credit Hours: 3 *Lecture Hours*: 28 *Lab Hours*: 28
IT Domain Coverage: -

CS_A 140: Computer Programming 1
The course introduces students to structured programming techniques. Topics include different control statements (sequence, selection, and repetition), functions, fundamental data types, and data structures (arrays and pointers). Upon successful completion of the course, students will solve computer problems by using structured programming techniques and adequate tools (text editor, compiler, and debugger).
Prerequisites: None
Credit Hours: 4 *Lecture Hours*: 42 *Lab Hours*: 28
IT Domain Coverage: ITE-SWF 1-4

CS_A 141: Computer Programming 2
This course will introduce the student to the concepts of object oriented programming.. Programming topics include data hiding/encapsulation and abstraction using classes and objects, inheritance, polymorphism, generic programming using template, operator overloading and file I/O Upon successful completion of this course.
Prerequisites: CS_A140
Credit Hours: 4 *Lecture Hours*: 42 *Lab Hours*: 28
IT Domain Coverage: ITE-SWF 7

CS_A 220: Computer Organization
This course introduces the general concepts of computer system organization. The students will be exposed to the instruction cycle and describe the organization of the CPU, I/O and Memory units.
Prerequisites: CS_A141, CS_A106
Credit Hours: 4 *Lecture Hours*: 42 *Lab Hours*: 28
IT Domain Coverage: -

CS_A 242: Data Structures
This course provides the students with understanding of the concepts on data representation and organization used in development of computer applications. The topics to be covered include: 1) Abstraction and encapsulation through Abstract Data Types (ADT), 2) Knowledge of basic and advanced data structures such as Linked Lists, Stacks, Queues, Trees and Graphs, 3) Knowledge of basic algorithmic analysis: Asymptotic analysis of worst and average complexity bounds; identifying differences among best, average, and worst case behaviors; big "O" notation, 4) Various sorting and searching algorithms are taught to illustrate the above concepts.
Prerequisites: CS_A141, CS_A104
Credit Hours: 4 *Lecture Hours*: 42 *Lab Hours*: 28
IT Domain Coverage: ITE-SWF 5-6

IT_A 280: IT Fundamentals
This course is intended to be at the introductory level and to provide foundation skills for subsequent courses. It provides an overview of the discipline of IT, describes how it relates to other computing disciplines, and begins to instill an IT mindset. The goal is to help students understand the diverse contexts in which IT is used and the challenges inherent in the diffusion of innovative technology.
Prerequisites: None
Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITE-CSP 1, ITE-GPP 1, ITE-IMA 1, ITE-IST 1, ITE-NET 1, ITE-PFT 1, ITE-SAM 1, ITE-SIA 1, ITE-UXD 1, ITE-WMS 1.

IT_A 300: Human-Computer Interaction
This course provides an introduction to the field of human-computer interaction (HCI), an interdisciplinary field that integrates cognitive psychology, design, computer science and others. This course will examine human performance, components of technology, methods and techniques used in design and evaluation of IT. Societal impacts of HCI such as accessibility will also be discussed. User-centered design methods will be introduced and evaluated. This course will also introduce students to the contemporary technologies used in empirical evaluation methods.
Prerequisites: IT_A280
Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITE-UXD 2-8

IT$_A$ 301: Project Management
This course discusses the processes, methods, techniques and tools that organizations use to manage their information systems projects. The course covers a systematic methodology for initiating, planning, executing, controlling, and closing projects. This course assumes that project management in the modern organization is a complex team based activity, where various types of technologies (including project management software as well as software to support group collaboration) are an inherent part of the project management process.
Prerequisites: IT$_A$280
Credit Hours: 4 *Lecture Hours*: 56 *Lab Hours*: 0
IT Domain Coverage: ITE-SIA 2-6

IT$_A$ 310: Cybersecurity Fundamentals
The Cybersecurity Fundamentals course will provide students with principles of data and technology that frame and define cybersecurity. Students will gain insight into the importance of cybersecurity and the integral role of cybersecurity professionals. The interactive, self-guided format will provide a dynamic learning experience where users can explore foundational cybersecurity principles, security architecture, risk management, attacks, incidents, and emerging IT technologies.
Prerequisites: IT$_A$301
Credit Hours: 4 *Lecture Hours*: 56 *Lab Hours*: 0
IT Domain Coverage: ITE-CSP 2-7

IT$_A$ 315: Technical Support
This course provides an intensive and comprehensive introduction to the basic communication and computer skills required to work in a technical support environment. Students will develop skills through various hands-on activities: to effectively troubleshoot personal computers; to use and implement safety strategies; to disassemble and assemble a computer; to install and troubleshoot operating systems; and to troubleshoot a variety of network and peripheral devices.
Prerequisites: IT$_A$300
Credit Hours: 3 *Lecture Hours*: 28 *Lab Hours*: 28
IT Domain Coverage: ITE-SAM 2-6

IT$_A$ 320: Introduction to Databases
This course will introduce the basic concepts in database systems and architectures, including data models, database design, database programming, and database implementation. It emphasizes on topics in ER model and relational databases, including relational data model, relational algebra and calculus, SQL, functional dependency and normalization, and database design process.
Prerequisites: CS$_A$242
Credit Hours: 3 *Lecture Hours*: 28 *Lab Hours*: 28
IT Domain Coverage: ITE-IMA 2-4

IT$_A$ 331: Fundamentals of n-Tier Architecture
This course examines the evolution of n-tier database application development, the roles of the various tiers in n-tier architectures. It explores the options for marshaling data across tiers and presents the advantages of using component-oriented designs.
Prerequisites: IT$_A$320, IT$_A$390
Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITE-IST 2-6

IT$_A$ 340: Computer Networks
This course is to select, design, deploy, integrate, and administer network and communication infrastructures in an organization. It includes fundamental concepts in the design and implementation of computer networks and their protocols. Also, it includes layered network architectures, applications, transport, congestion, routing, data link protocols, local area networks. An emphasis will be placed on the protocols used in the Internet. A top-down approach will be emphasized during the course starting from the application layer down to the data link layer.
Prerequisites: IT$_A$360
Credit Hours: 4 *Lecture Hours*: 56 *Lab Hours*: 0
IT Domain Coverage: ITE-NET 2-7

IT$_A$ 360: Operating Systems
This course is about the basics of computer operating systems, including configuration, file systems, security, administration, interfacing, multitasking, and performance analysis. Parallelism or concurrency aspects are explained using the concepts of process management, synchronization, deadlocks, job and process scheduling.
Prerequisites: CS$_A$220, CS$_A$242
Credit Hours: 4 *Lecture Hours*: 56 *Lab Hours*: 0
IT Domain Coverage: ITE-PET 2-5

IT$_A$ 390: Web Systems
This course covers the design, implementation and testing of web-based applications including related software, databases, interfaces and digital media. It also covers social, ethical and security issues arising from the Web and social software.
Prerequisites: IT$_A$315
Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITE-WMS 2-7

IT$_A$ 410: IT Security and Risk Management
This course provides the principles and topics of Information Technology Security and Risk Management at the organizational level. Students will learn critical security principles that enable them to plan, develop, and perform security tasks. The course will address hardware, software, processes, communications, applications, and policies and procedures with respect to organizational IT Security and Risk Management. *Prerequisites*: IT$_A$310

Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITE-CSP 8-14

IT_A 412: IT Governance

The course covers IT governance framework and roadmap for planning and implementing a successful IT governance process and drills down into its major components in more detail. Key topics covered are: executive View of IT governance, overview of Industry Best Practice Standards, Model and Guidelines covering some aspect of IT governance. In addition, the course includes: principles of Business/IT Alignment Excellence, principles of Program/Project Management Excellence, principles of IT Service Management and Delivery Excellence and principles of Vendor Management and Outsourcing Excellence. Finally, it presents some lessons learned and critical success factors and some select case studies.
Prerequisites: IT_A410
Credit Hours: 3 *Lecture Hours*: 42 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 2-7

IT_A 420: Database Administration DBMS

This course introduces a variety of database administration topics, including capacity planning, database management system (DBMS) architecture, performance tuning, backup, recovery and disaster planning, archiving, reorganization and defragmentation.
Prerequisites: IT_A320
Credit Hours: 3 *Lecture Hours*: 28 *Lab Hours*: 28
IT Domain Coverage: ITE-IMA 5-7

IT_A 490: Learning & Thinking & Research

The course includes intensive study of a broad selection of conceptual and theoretical problems in information technology. A written student research project and an oral presentation are required.
Prerequisites: IT_A340, IT_A320
Credit Hours: 1 *Lecture Hours*: 14 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 6-10

IT_A 491: Practical Training

Training is an important aspect of the educational process. Students are required to join an IT center in a government or private sector as a full time for at least 8 weeks to complete 280 hours. The aim of the student training is to acquire the experience in applying what he learned in real life and in team working as well as get familiar with the work environment in his field.
Prerequisites: the student's successful completion of all IT courses required to complete up to semester five.
Credit Hours: 1 *Lecture Hours*: 0 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 8-11

IT_A 492: Senior Information Technology Project Phase 1

The course aims to introduce the required techniques for implementing systems, writing technical reports and the skills for presenting the work for audiences. This course will particularly focus on topics which are related to the field of Information Technology. The course will also provide guidance to the students in selecting their projects, understanding the research process as well as the tools needed to support implementing the system and writing its proposal and report. The student should get the supervisor approval for his proposal during this course.
Prerequisites: IT_A390, IT_A310, IT_A490
Credit Hours: 2 *Lecture Hours*: 28 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 3,4,6-10

IT_A 493: Senior Information Technology Project Phase 2

This a continuation of the graduation project started in IT_A492. The focus will be in this part on low-level design, implementation, testing and quality assurance as well as management of the project. The outcome of this project must be a significant Information Technology product, employing knowledge gained from courses through the curriculum. Students must deliver the code, a final report and must present the demonstration of their work.
Prerequisites: IT_A492
Credit Hours: 4 *Lecture Hours*: 0 *Lab Hours*: 0
IT Domains Coverage: ITE-GPP 12

B.5 Curriculum B: Typical IT Curriculum – United States

Information Technology Program
Administered by a School of Technology

B.5.1 Program Goals and Features

This program leads to a bachelor's degree in information technology, as might be offered by a program housed in a school of technology, in a college of engineering and technology. Some of the required courses are offered in a department of computer science. This program usually has multi-course sequences in programming, web systems, databases, networking, human-computer interaction, and cybersecurity. This program is oriented more towards breadth in computing, rather than depth in any specific area, but allows for, and recommends, at least one depth area in applications of computers. Graduates are able to be competitive in any general area of applications of computers.

B.5.2 Summary of Requirements

This program of study contains 3 required computer science courses (9 semester credit hours), 11 required information technology (IT) courses (36 semester credit hours), 3 elective IT courses (9 semester credit hours), and 5 elective courses (15 semester credit hours) in a computer application depth area or a minor. The IT elective courses may be chosen from any non-required IT courses; the depth area electives may be chosen from any area of computer applications. Lab hours are present in all IT courses, giving students a very strong component in experiential learning. The IT capstone experience occurs over two semester courses in the senior year, allowing for a substantial and complete design experience with an open problem. It also includes requirements in math and science, ethics, global considerations, and technical writing. This curriculum requires 41 courses, distributed as follows.

Topics	***Semester Credit Hours***
Required information technology	36
Information technology electives	10
Minor or Application domain electives	18
Mathematics	7
Required computer science	9
Natural science (physics, biology)	9
English composition, humanities, social sciences	21
Innovation, global, ethics	4
Free electives	6
Total Hours	**120**

Since a BS degree generally requires at least 120 semester credit hours, there remains six semester credit hours that may be allocated as appropriate at a given institution.

B.5.3 Four-Year Model for Curriculum B

IT: offered in the information technology department
CS: offered in the computer science department

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
IT$_B$ 101	IT Cornerstone	3	IT$_B$ 102	Intro to Computer Systems	3
CS$_B$ 101	Intro to Computer Programming	3	CS$_B$ 201	Foundations of CS 1	3
Math 120	Calculus 1	4	Physics 120	Physics 1	3
Am Htg	American Heritage	3	Writing 150	Composition	3
	Total Semester Credit Hours	**13**		*Total Semester Credit Hours*	**12**
Semester 3			**Semester 4**		
IT$_B$ 201	Web-based IT	4	IT$_B$ 202	Computer Architecture	3
Phys 121	Physics 2	3	CS$_B$ 202	Discrete Structures	3
Bio 100	Biology	3	Stat 201	Introductory Statistics	3
Hist 201	History of Civilization I	3	Hist 202	History of Civilization II	3
	Total Semester Credit Hours	**13**		*Total Semester Credit Hours*	**12**
Semester 5			**Semester 6**		
IT$_B$ 402	IT Seminar	0.5	IT$_B$ 402	IT Seminar	0.5
IT$_B$ 301	Database Princ & Apps	3	IT$_B$ 302	Operating systems	3
IT$_B$ xxx	Digital Communications	4	IT$_B$ 303	Networks	3
TK$_B$ 201	Globalization; Ethics	3	IT$_B$ 304	Human Comp Interact	3
Engl 301	Technical Writing	3		Minor or applic domain elective	3
	Minor or applic domain elective	3		Minor or applic domain elective	3
	Total Semester Credit Hours	**16.5**		*Total Semester Credit Hours*	**15.5**
Semester 7			**Semester 8**		
IT$_B$ 451	Senior Capstone I	3	IT$_B$ 447	Senior Capstone II	3
IT$_B$ xxx	IT Tech Elect	3	IT$_B$ xxx	IT Tech Elect	3
IT$_B$ 420	Info Assurance & Security	3	Econ 110	Principles of Economics	3
IT$_B$ 402	IT Seminar	0.5	IT$_B$ 402	IT Seminar	0.5
	Minor or applic domain elective	3		Arts or Letters	3
	Minor or applic domain elective	3		Minor or applic domain elective	3
	Total Semester Credit Hours	**15.5**		*Total Semester Credit Hours*	**15.5**

B.5.4 Mapping of Information Technology Curricular Framework to Curriculum B

Refer to section B.1.2 for an explanation of this table.

Essential Domains / Courses	CSP	GPP	IMA	IST	NET	PET	SAM	SIA	SWF	UXD	WMS
IT_B 101	1		1	1	1	1	1	1	1	1	1
IT_B 102											
IT_B 201				2-6							2-7
IT_B 202								2-6			
IT_B 301			2-7								
IT_B 302						2-5					
IT_B 303					2-7						
IT_B 304										2-8	
IT_B 401							2-6				
IT_B 402		2, 11									
IT_B 420	2-14										
IT_B 451		3, 4, 6-10									
IT_B 452		12									
CS_B 101									1-4		
CS_B 201									5-7		
CS_B 202											
TK_B 201		1, 5									
Subdomains Covered	**1-14**	**1-12**	**1-7**	**1-6**	**1-7**	**1-5**	**1-6**	**1-6**	**1-7**	**1-8**	**1-7**
Minimum Essential Hours	**40**	**25**	**40**	**20**	**35**	**15**	**20**	**20**	**30**	**20**	**25**

B.5.5 Curriculum B – Course Summaries

IT_B 101: IT Cornerstone
Planning and preparing for a successful career in information technology. Developing skills with computers, problem solving, studying, and time management. Comparing information technology to computer science, computer engineering, and information systems. Introduction to networking, databases, computing systems and platforms, cybersecurity, web systems, and computer programming.
Prerequisite: None
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-CSP 1, ITE-IMA 1, ITE-IST 1, ITE-NET 1, ITE-PET 1, ITE-SAM 1, ITE-SIA 1, ITE-SWF 1, ITE-UXD 1, ITE-WMS 1

IT_B 102: Introduction to Computer Systems
How a computer works, from hardware to high-level programming language. Logic circuits, Boolean algebra, computer instructions, assembly language, binary arithmetic, and C programming.
Prerequisite: CS_B 101
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: -

IT_B 201: Fundamentals of Web-Based Information Technology
Web technologies including distributed architecture, networking, database concepts, client and server development, infrastructure management, and web system integration.
Prerequisites: IT_B 101, CS 101
Credit Hours: 4 *Lecture Hours*: 32 *Lab Hours*: 24
IT Domain Coverage: ITE-IMA 2-7

IT_B 202: Computer Architecture and Organization
Principles of computer hardware and instruction set architecture. Subjects include: internal CPU organization and implementation, peripheral interconnect and IO systems, and low-level programming and security issues.
Prerequisites: IT_B 102, CS 201
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-SIA 2-6

IT_B 301: Database Principles and Applications
Database theory and architecture; data modeling; designing application databases. Query languages, data security, database applications on the Web.
Prerequisite: CS_B 202
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-IMA 2-7

IT_B 302: Operating Systems
Applying and using computer operating systems. Configuration, file systems, security, administration, network interfacing, multitasking, multiuser, device driver installation. Analyzing operating system performance.
Prerequisites: CS_B 101, IT 202
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-PET 2-5

IT_B 303: Computer Networks
Computer networks. Local and wide-area networking for enterprises and service providers. Workgroups/routers/hubs/switches; network server administration; Internet protocols and routing; security and privacy.
Prerequisite: CS_B 202
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-NET 2-7

IT_B 304: Human-Computer Interaction
User experience design techniques and best practices including requirements analysis, usability studies, prototyping methods, evaluation techniques, and cognitive, social, and emotional theories.
Prerequisite: IT_B 201
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-UXD 2-8

IT_B 401: System Administration and Maintenance
Administration activities and domains for computing systems, including performance analysis, backup, and recovery.
Prerequisite: IT_B 302
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-SAM 2-6

IT$_B$ 402: IT Seminar
Meet with IT professionals to learn about professional issues and responsibilities, employability skills, and careers in IT. Eight hours/semester, four semesters.
Prerequisite: Sophomore-level standing in program
Credit Hours: 2 *Lecture Hours*: 24 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 2,11

IT$_B$ 420: Information Assurance and Security
Computer security principles. Incident prevention and management. Information assurance dimensions of availability, integrity, authentication, confidentiality and non-repudiations to ensure transmission, storage, and processing of information.
Prerequisites: IT$_B$ 301, 302, 303
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-CSP 2-14

IT$_B$ 451: Senior Project/Capstone I
IT senior project proposal and feasibility studies. Project management, teamwork principles, intellectual property, supplier interactions, identifying and using professional technical literature, oral and written presentations.
Prerequisites: IT$_B$ 301, 302, 303
Credit Hours: 3 *Lecture Hours*: 24 *Lab Hours*: 24
IT Domain Coverage: ITE-GPP 3, 4, 6-10

IT$_B$ 452: Senior Project/Capstone II
Senior project design and integration. Second class of two-course sequence. Implementing design. Project management, teamwork, and presentations.
Prerequisite: IT$_B$ 451
Credit Hours: 3 *Lecture Hours*: 16 *Lab Hours*: 32
IT Domain Coverage: ITE-GPP 12

CS$_B$ 101: Introduction to Computer Programming
Introduction to object-oriented program design and development. Principles of algorithm formulation and implementation.
Prerequisites: None
Credit Hours: 3 *Lecture Hours*: 32 *Lab Hours*: Programming Assignments
IT Domain Coverage: ITE-SWF 1-4

CS$_B$ 201: Data Structures and Algorithms
Fundamental data structures and algorithms of computer science; basic algorithm analysis; recursion; sorting and searching; lists, stacks, queues, trees, hashing; object-oriented data abstraction.
Prerequisites: CS$_B$ 101
Credit Hours: 3 *Lecture Hours*: 32 *Lab Hours*: Programming Assignments
IT Domain Coverage: ITE-SWF 5-7

CS$_B$ 202: Discrete Structures
Introduction to grammars and parsing; predicate and propositional logic; proof techniques; sets, functions, relations, relational data model; graphs and graph algorithms.
Prerequisites: CS$_B$ 201
Credit Hours: 3 *Lecture Hours*: 32 *Lab Hours*: Programming Assignments
IT Domain Coverage: -

TK$_B$ 201: Foundations of Global Leadership
Foundational principles and practices of individual and organizational leadership in a global context from an integrated moral, technical and social perspective. Emphasis on developing integrity, valuing and leveraging diversity, acquiring and applying leadership skills.
Prerequisites: Sophomore-level standing in program
Credit Hours: 3 *Lecture Hours*: 32 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 1, 5

Appendix C:
Information Technology Interdisciplinary Curricula Samples

[Completion of this appendix will appear in a future version of this report.]

Appendix D:
Contributing Reviewers

[Completion of this appendix will appear in a future version of this report.]

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Additional Items

[Completion of this section will appear in a future version of this report.]