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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IT2017 Task Group

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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 develop and implement modern IT curricula. 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 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.

> *Having just knowledge is not sufficient to be productive in the changing information technology world. IT competencies require skills and dispositions that complement knowledge to achieve professional expectations of a modern workplace. The mission of the IT2017 project is to produce globally accepted documents of IT competencies appropriate for undergraduate degree programs that meets the growing demands of the changing technological world and 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 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 feedback and support from employers of IT graduates 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, and forecasted advancements in the next decade. Computing technologies have developed rapidly over this time in ways that have had a profound effect on curriculum design and learning.

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 preparation for graduate studies. The third goal is critical; most graduates of undergraduate information technology programs will seek employment in industry, government, and other workplace 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 IT competencies 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 and curriculum development.

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, 2016)
- Computer science (2001, 2008, 2013)
- Information systems (1997, 2002, 2006, 2010, 2016) 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" and known as CC2005 report [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 view the computing curricular guidelines as minimal 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 role of IT in computing and presents a new definition of the IT discipline to reflect innovations that have transformed the field. It also highlights characteristics expected of information technology graduates and identifies areas of research relevant to IT/. Chapter 3 highlights the importance of professionalism in the practice of information technology. Chapter 4 discusses the meaning of competencies and its relationships to information technology. It explores some theoretical aspects of competencies and proposes an operational definition of IT competencies.

Chapter 5 discusses an industry perspective toward information technology. It includes current data and graphs related to IT competencies and skills viewed from IT employers. Chapter 6 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 of the report, the perspectives from industry, and professional practice. The chapter also articulates various IT domains of the curricular framework, the percentages of time devoted to an undergraduate degree IT program, mathematics and science requirements, and various competencies an individual need to become an effective professional in information technology.

Chapter 7 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 8 discusses some challenges that may arise when implementing or maintaining information technology programs such as curriculum design, computing resources, and faculty issues.

The bulk of the material in the report appears as five appendices. Appendix A presents a subset of the Enterprise Skills Frameworks in the Enterprise Information Technology Body of Knowledge (EITBOK) report currently under development by the IEEE Computer Society. Appendix B suggest IT performances related to various IT domains and their subdomains. These performances may be used to develop course learning outcomes for a given IT course or possible assessments to measure student performance. Appendix C illustrates typical sample curricula with related mappings of the framework and course descriptions as they might appear at different academic institutions. Appendix D provides samples of other information technology programs (e.g., interdisciplinary, three-year, 2+2, etc.). Appendix E 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. 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. . IT competencies frame the structure and inform the content of the IT curricular framework in this report. The task group established desired competencies and allowed IT domains to follow from the competencies. Competencies describe knowledge, skills, and dispositions and represent the driving force in designing and implementing IT curriculum for individual degree programs in IT.

3. *Revisions must include longevity and avoid buzzwords and current jargon*. Due to the rapidly evolving nature of information technology, the goal is to make the content of this report more timeless. The authors have tried to remove any hype or current jargon from the domains and competencies. Nevertheless, the task group recommends that the professional associations in information technology continue the periodic review process that allows updates of individual curricular recommendations on a recurring basis.

4. *The IT curricular framework must continue to be flexible and remain as small as practical.* There are many careers that graduates from IT programs enter. Those careers show an enormous diversity and the competencies required for each consequently vary widely as well. The design of the IT curricular framework allows programs

considerable freedom in tailoring the curriculum to the needs of its students, other institutional stakeholders, and local industries. For this purpose, the task group recommends essential competencies that a program *must* meet and it provides 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. IT graduates must therefore acquire competencies that enable them to perform integrative tasks successfully, apply system approaches to developing and administering secure technological solutions, and support users to accomplish their personal, organizational, and societal goals.

6. *The IT curricular framework must reflect the relationship of information technology to other computing disciplines.* The first version of this document followed the format developed in other documents within this CC2005 series, particularly CC2001 for computer science. 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 expectations.

7. *This document aims at four-year programs offered at institutions of higher learning, but should also be applicable in other contexts.* Even though curricular requirements of IT degree programs differ from country to country, the task group intends this document to be useful for 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.

8. *The development of this report must have a broad foundation*. 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 report must offer significant guidance in terms of implementation of the IT curricular framework.* Although it is important for this report to articulate IT domains and competencies, 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.

1.5 Recurring Themes and Overtones

The IT2017 report promotes sound principles regarding ways information technology permeates society on a global scale. Notwithstanding, it is not possible to cover all modes of thinking and all ways of learning. For example, the use of experiential learning is not a full part of the report even though the report does not preclude it. Individual institutions and their faculties should use innovative strategies to engage students in the learning process. For example, institutions can utilize their own IT services to develop “onsite learning” by which upper-level students could shadow IT employees or be part of existing IT teams. Experiences such as these promote leadership and help develop interpersonal skills in the preparation of becoming IT professionals.

There are many pedagogical challenges and opportunities involving information technology., Although the report underscores the need for accessibility for all people, it does not discuss how to address the situation. For example, game-based learning could be part of a process to achieve accessible learning. The task group believes such attention should take place at the institution level as well as through ongoing research by scholars and practitioners. As another example, service outsourcing and cloud-based services affect IT industries and therefore, the ability of graduates to acquire IT professional positions. While the report addresses cloud computing, the task group again believes that learning environment support for teaching and learning cloud computing should take place at institutions and through ongoing research.

One underlying theme of the report is the development of IT talent from all sectors and groups in our society. The lack of diversity limits creativity and productivity, excludes many potential qualified individuals, and therefore is of significant concern to many prominent employers. For example, the low proportion of women in IT has received a lot of attention and raised concerns in academia and industry. This report recognizes the importance of diversity and recommends that IT departments promote research-based practices known to attract and retain greater diversity of students.

The task group has placed inclusion at the core of its activities from the very first step of forming its membership. Our twelve-member group has diverse composition by gender, type of work affiliation, geography, and international professional societies:

- Number of industry/government: 3, academic: 9
- Number of countries: 5
- Number of continents: 3
- Number of women: 7; men: 5
- Number of international professional societies: 4
- Task group chair: woman
- Executive committee: 3 women, 2 men

The task group is keenly aware that it cannot satisfy the desires of all people. It has made every effort to position the IT discipline within the broader computing landscape. As a global document, the report provides examples from diverse communities and is not prescriptive in its recommendations.

1.6 Global Improvement

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 IT competencies so they can achieve professional success in their future careers.

Chapter 2: The Information Technology Discipline

2.1 The Role of IT within the Computing Disciplines

The increased importance and global reach of computing technology in all aspects of today's society was the basis for the emergence of the information technology discipline. The youngest still among the current five computing disciplines, the information technology discipline was born in 2008 with the release of the first ACM/IEEE-CS report on the curriculum guidelines for undergraduate programs in IT [Lun1]. Since then, its sister disciplines have already undergone updates and revisions (Figure 2.1). Information systems updated its curriculum in 2010 [Top1]. Computer science completed its revisions in 2013 [Joi1], followed by software engineering in 2014 [His1]. Computer engineering published its curriculum guidelines in 2016 [Imp1].

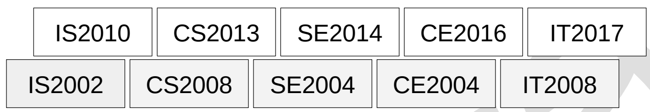

Figure 2.1: Timeline of the computing curricula recommendations reports

As the computing field continues to advance, ACM, along with leading professional and scientific computing societies, will continue to align curriculum recommendations of existing disciplines to the fast-changing landscape of computing technology. Additional reports for new computing disciplines, such as data science and cybersecurity, will benefit from similar support.

In the context of undergraduate computing education, developing curriculum guidelines for Information Technology poses multiple challenges: rapid technological advances in computing; emergence of new computing areas of study; persisting skill gap between employers' expectations and graduates' preparation; continuing participation of women and other underrepresented groups in IT programs and careers; limiting the size of a realistic and implementable curriculum; increased variety of careers in IT; evolving professional practices; and differentiating the Information Technology discipline from other computing disciplines.

The seminal work of the Computing Curricula 2005 (CC2005) report [Sha1] defined the landscape of computing disciplines, described their history, evolution, and shared identity, and created powerful visualizations of how these computing disciplines relate to each other. The report defines computing, in a general way, to mean any goal-oriented activity requiring, benefiting from, or creating computing devices and computational artifacts. In that sense, computing includes the theory and science of computation, designing and building of software and hardware systems, and creating and managing new computing technologies for a wide variety of purposes to meet the needs of people, organizations, and society at large. This definition exposes three inter-related perspectives on computing:

- *Scientific and theoretical perspective*: Advancing the underlying science and theory of computation that enables computing discoveries.
- *Technical and engineering perspective*: Designing and building computing machines (devices, systems, services).
- *Business, professional, and societal perspective*: Ultimately, the purpose of creating and managing computing technologies is to serve individuals, organizations, and society at large.

We note that computing technologies do not exist in the abstract. In a digital platform economy [Par1], computing technologies become the fabric that connects diverse participants, producers and consumers, and enables meaningful value exchanges among all participants.

Of all computing disciplines, information technology is the most integrative: "the depth of IT lies in its breadth" [Lun1]. Two graphical representations captured its disciplinary identity in the CC2005 and IT2008 reports, as reproduced in Figure 2.2.

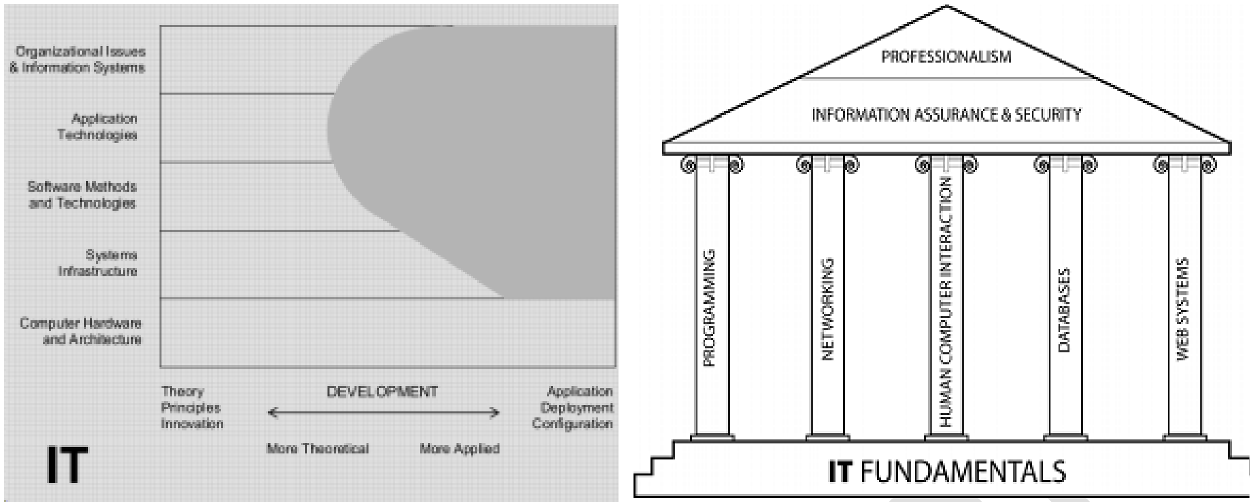

Figure 2.2: Graphical representations of the information technology discipline a decade ago.
Source: Computing Curricula 2005 (left) and IT2008 (right) reports

To the left there is the view of the IT discipline offered by the CC2005 report: the computing disciplinary space has two dimensions, theory and practice dimension (horizontal) and infrastructure and organizational dimension (vertical); in this space, the IT discipline distinguishes from other computing disciplines by being more applied than theoretical and by addressing infrastructure systems and application technologies. To the right there is the IT2008 report's depiction of the IT discipline. The report organized its key curricular components into five pillars, programming, networking, human-computer interaction, databases, and web systems, built on a foundation of IT fundamentals and overarched by information assurance and security and professionalism.

2.2 Driving Forces through IT Innovations

At the time the first IT Curriculum Guidelines report was released in 2008, Apple had developed the iPhone, Facebook had been born, Amazon had launched its Kindle e-reader, YouTube had become the world's most popular video sharing website, Google had released the Android operating system, and mobile broadcast internet access had adopted 4G standards. These innovations have opened doors to the coming of what Erik Brynjolfsoon and Andrew McAfee call the second machine age [Bry1]. If the industrial revolution or first machine age was about complementing human work with the automation of manual labor and horsepower, the second machine age substitutes for humans the automation of knowledge and software-driven machines.

The proliferation of web services, emergence of mobile computing, social media, high-speed wireless networks, and expansion of data centers have marked the birth of the academic field of information technology in 2008. Almost a decade later, IT capabilities have become embedded in everything around us. The most notable IT innovations that inform the IT domains of this report's IT Curricular Framework are as follows.

- *Mobile applications* have been the leading digital platform since 2016, with total activity on mobile devices accounting for two-thirds of digital media time spent [Lel1], when mobile overtook fixed internet access in 2014.

- *Social platforms* that combine social media, social collaborations, and social feedback (reviews, comments, and 'likes') have contributed to integrating social technologies with business applications, ranging from social customer relationship management to internal communications and collaboration, and to the business public social site.

- *User experiences* are replacing the traditional user interfaces containing windows, icons, menus, and mouse clicks with contemporary integrations of touch, gesture, voice, gaze tracking, real-time web implementation, and video in the design, implementation, and evaluation of user interfaces. For example, HTML5 and asynchronous web development techniques (e.g., asynchronous JavaScript and data interchange formats) have emerged to provide a longer-term solution to cross-platform mobile web apps that blur the distinction between mobile native and mobile web applications. These advances blur the distinction between desktop, portable and mobile applications and require technical skills for blending experiences across environments, operating systems, and hardware platforms.

- *Internet of things* and *big data* were among the top ten strategic technology trends announced annually by Gartner, Inc. in 2011. These developments coincide with General Electric's move to open GE Digital, whose most important project was the launch of Predix in 2016. An open source, cloud-based IoT platform, Predix is to industrial apps what Android is to mobile apps or Amazon Web Services is to web apps. IoT platforms such as Predix combine data analytics and cloud computing to build industrial apps to improve efficiency and productivity of industrial machines, from aircrafts to power plants and manufacturing [Woo1].

- *Cybersecurity* advances must preserve the internet's societal and economic benefits. Social media's explosion in the 2000s, accelerated adoption of smart mobile devices, centrality of cloud computing in many enterprises' data and service architecture made cyberspace an integral component of society's fabric. The more society relies on the benefits of IT, the greater the danger of malicious cyber activities. Computing systems should operate properly in hostile environments with architectures that have dynamic, real-time defenses to complement firewalls and virus scanners [Nat1]. Cybersecurity risk management comprises the full range of activities undertaken to protect IT and data from unauthorized access and other cyber threats, to maintain awareness of cyber threats, to detect anomalies and incidents adversely affecting IT and data, and to mitigate the impact of, respond to, and recover from incidents [Peo1].

- *Automation* is becoming a global force that will transform economies and the workforce. Robots and computers can not only perform a range of routine physical work activities better and more cheaply than humans, but are also increasingly capable of automating cognitive capabilities [McK1].

The earliest this report's guidelines will come to fruition is early 2020s, when graduates of programs that are knowledgeable of these guidelines enter the workforce or further their academic studies. It is the responsibility of this report to expand the horizon of IT innovation to 2020s so its recommendations remain sound and relevant a decade from now. Garner Research's forecast for 2025 IT innovations proposes three themes the will transform the digital economy [Cea1]: evolving digital mesh of smart machines; the rise of algorithmic business models and automation; and IT platforms that enable new ecosystems, whether in retailing (Amazon Prime platform), taxi business (Uber platform), or lodging (Airbnb platform). The revolutionary business power of the IT platforms will have a significant impact on the digital economy of the near future [Par1].

2.3 Definition of the Information Technology Academic Discipline

Worldwide, the term "information technology" generally refers to all aspects of computing and its integration into all aspects of today's society and digital platform economy. Organizations of every kind are dependent on information technology and computing systems that must work properly and efficiently, be secure, and scale with organizational objectives and customer needs. IT professionals select computing products and services, integrate them to enhance supported environments, and develop, adapt, and manage computing technologies to meet the organization's goals and business objectives. The IT innovations are the object of study of the Information Technology discipline. These innovations frame the questions IT professionals and researchers pose and inform the methods and practices by which IT complex problems are solved, and new discoveries are made. This report proposes the following definition of the information technology discipline:

Information Technology is the study of systemic approaches to select, develop, apply, integrate, and administer secure computing technologies to enable users to accomplish their personal, organizational, and societal goals.

Academic disciplines evolve with their object of study. The fact that information technology programs emerged to meet demand from employers has had a significant effect on the evolution of the discipline. Today's IT innovations and discoveries break the conventional silos of IT domains. Drawing today's picture of the IT discipline should capture the interrelated and evolving IT domains over the next decade.

This report's depiction of IT is like a tapestry (e.g., Figure 2.3) that weaves interrelated studies and learning activities to prepare graduates for the complexities of a changing world. The tapestry metaphor refutes artificial boundaries that separate content, practices, and contexts of IT learning experiences. Instead, it emphasizes structural and functional connections among many and varied aspects of IT and expresses creativity and innovations that IT programs can bring forward with support from this report's guidelines.

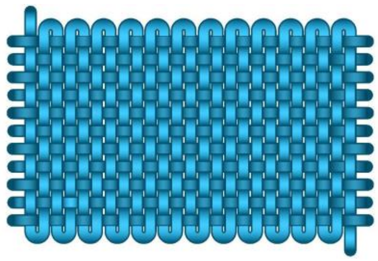

Figure 2.3: Generic tapestry (Courtesy of Richard Fry)

2.4 IT Graduate Profile and Professional Readiness

The IT graduate is a collaborative problem solver, skilled practitioner, or applied research investigator who enjoys getting technology to work effectively and meet user needs in a variety of settings. IT graduates work collaboratively to integrate new technologies in the workplace and community and ensure a superior and productive experience for the user and all the organization's functions. In the corporate environment, IT graduates apply their understandings of system integration, development, and operation and deploy and manage IT services and platforms that meet the business goals and objectives of the organization. In the community, IT graduates use their expertise in implementing a wide range of IT solutions to support community members' projects and activities. IT graduates are professionals prepared to perform duties in an ethical manner. They are familiar with the various laws and regulations that govern the development and operations of the IT platforms they maintain. IT graduates can explain and justify professional decisions in a language that both management and clients understand. They are aware of the budget implications of technological alternatives and are able to defend budgets properly. IT graduates have extensive practice with properly securing IT networks, applications, data centers, and online services. They seek secure technology solutions without unduly adversely affecting the ability of users to accomplish their goals

The IT graduate characteristics inform the educational outcomes and IT competencies that are essential to prepare students for success after graduation by securing modern jobs and advancing their careers. IT program accreditation considerations are another factor in defining an IT graduate profile [Abt1]. The ABET Computing Accreditation Commission has recently proposed criteria changes that acknowledge the significance of the latest work on "defining the content and boundaries of the various computing curricula" [Abt2] in the recent ACM curricula reports for Information Systems (2010) [Top1] and Computer Science (2013) [Joi1]. Relevant to this report and the IT graduate profile is the strengthening of the ABET CAC Curriculum Criterion 5 by requiring that all computing programs include information assurance and security principles and practices in their curricula. Equally important is the revision of the Student Outcomes in Criterion 3 to convey clear expectations of student learning that are shared by all computing disciplines. Other recent curriculum framework for secondary education, K-12 CS Computer Science Framework [Kcs1] and Advanced Placement CS Principles Framework [Cba1] frame their guidelines with what kinds of learning students need to demonstrate and higher-level competencies that matter to their success in adult life, including modern jobs and further academic and career paths.

Considering accreditation updates and curriculum frameworks that integrate disciplinary content with authentic practices, the educational outcomes of IT graduates in this report describe competencies that students develop progressively through their program of study and can demonstrate upon graduation. The educational outcomes that define the IT graduate profile are as follows.

1. Analyze complex, real-world problems to identify and define computing requirements and apply computational approaches to the problem-solving process.

2. Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the IT discipline.
3. Communicate effectively with diverse audiences technical information that is consistent with the intended audience and purpose.
4. Make informed judgments and include unique perspectives of others in computing practice based on legal and ethical principles.
5. Function effectively on teams and employ self- and peer-advocacy to address bias in interactions, establish goals, plan tasks, meet deadlines, manage risk, and produce deliverables.
6. Identify and analyze user needs and consider them during the selection, integration, and administration of computer-based systems.

2.5 Research in IT

IT is evolving rapidly. Making definitive statements about research in IT continues to be a challenge for several reasons, including the following.

<u>*Focus on practice*</u>: – IT emphasizes proficiency in learning IT core concepts combined with authentic practice. 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 four-year 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. Practice and educational programs inform the development of a research agenda in the IT community. More accurately, the research agenda simply emerges from the practice.

<u>*The computing milieu*</u>: – *The Computing Curricula Overview Report* (CC2005) 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 sometimes even contention among the disciplines. This intermingling can follow many dimensions that might separate the disciplines. While some leading journals relate to specific 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 in 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 [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.

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 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 those early discussions continue to present fertile ground IT research:

- *Continuous 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. Successful IT practice requires principles and methods for conducting this analysis.
- *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.
- *Cybersecurity*–Since protection is only as good as the weakest point in the system, security and information assurance present challenges in IT, where the scope of concern encompasses the total system.
- *Development and operations interplay*– Continuous release and deployment of an IT application in a user environment often changes that environment in subtle ways. Being able to predict how an IT application is likely to change the user environment would help ensure successful integration of continuous development and operations.

The list above captures 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 systemic approaches to select, develop, apply, integrate, and administer secure computing technologies to enable users to accomplish their personal, organizational, and societal goals.

Chapter 3: Preparing Contemporary IT Professionals

As the field of computing continues to change, so must the information technology curriculum and other computing disciplines to ensure graduates are prepared to contribute value to enterprises. Understanding the value of professional practice is critical for most students in information technology programs since most will enter the workforce upon graduation.

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.

3.1 Rationale

It is important to incorporate professional preparedness into the curriculum because graduates of information technology programs will face real-world issues in the workplace such as the needs of the organization, the public's demand for high 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 for those who hire them. Indeed, as students learn more about how to act professionally and the 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 the IT profession.

Industry has 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 5 on Industry Perspectives of this report for a more in-depth discussion related to employer- 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 significant factors in producing web systems with many 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.

- Develop and promote codes of ethics such as the ACM Code of Ethics and Professional Conduct [Acm2], the CompTIA 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.
- 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].
- Develop and refine curricular guidelines such as the ones in this report and its predecessors.
- Participate in the development of accreditation guidelines that ensure the inclusion of professional practice in the curriculum.
- Support the formation of student chapters that encourage students to develop a mature attitude toward professional practice.

- 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 prepared 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; they should be able to practice their profession in a mature and ethical way.

3.2 Professional Practice

Many strategies currently exist for incorporating professional practice into the curriculum. Among the most common characteristics of these strategies are IT courses with learning experiences that emphasize team work, authentic projects, outside clients, relevant aspects of IT work, employers' direct involvement, and use of professional tools and platforms. Alternatively, professional practice might be part of courses that come from outside information technology departments. For example, students gain practice with technical writing or public presentations is courses offered by English or communication departments. 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.

IT programs should adopt a curriculum that integrates learning of professional practice through courses, seminars, and credit-bearing work experiences. The following list outlines several possibilities.

- *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 their own projects, but they may also elicit projects from outside clients. Although the emphasis of the course is on project management 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 impacts of computing, social issues of computing on society, computing careers, legal and ethical responsibilities, international computer laws and the computing profession.

- *Practicum/Internship/Co-op Programs*: These programs receive sponsorship by institutions (preferably) or departments 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 engage in their four-year degree. The students who do a co-op or internship generally do so off campus and may interrupt their education for a summer or a semester. Students usually receive payment for their work, and in some cases, they may also receive course credit.

- *Team-based DevOps Courses*: These courses emphasize the process of IT system development and operations and typically include a team project and continuous value delivery. Course competencies include continuous planning, development, integration and testing, release and deployment, and infrastructure monitoring and optimization. Professional practice specific to these courses emphasizes shared goals, responsibility, collective ownership, constant communication, and continuous experimentation.

- *Seminars on Trends and Change in IT*: Many new types of work have emerged in recent years such as security specialists, big data analysts, user experience designers, full-stack developers, software-defined networking architects, 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.

- *Entrepreneurial Innovation Courses*: The IT industry needs 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 organizational functions of engineering, management, communication and commerce. The students will evaluate, research, write, and present organization 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 philosophical ethics, psychology, organization management, economics, technical communications, and engineering design.

3.3 Preparing for the Global Workplace

Support for the inclusion of professional practice preparation in the curriculum can come from many sources. The following highlights employers' responsibilities, 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.

3.3.1 Workplace Awareness

Most students graduating from universities go on to employment in the private or public sector industries. In their role as the primary employer 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 IT competencies 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 employers can support the education process is to encourage their employees to play a greater role in helping to prepare students. These employees can offer support in several ways:

- Function in the role of mentors to students working on projects.
- Give special presentations to classes about their firm, their work, and their development processes.
- Take part-time positions as adjunct instructors to strengthen a university's course offerings.
- Provide in-house instructional materials and/or classes to faculty and students in development, operations, or specialized research.
- Serve on industrial advisory boards and provide valuable feedback to the department and institution about the strengths and weaknesses of the students.

In each of these ways, employers establish long-term, mutually beneficial collaborations with IT departments from where they recruit adequately prepared 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 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, employers 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 and 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, organizations in the private/public sector and in education can work together to produce students highly competent in a modern and competitive workplace. 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.

3.3.2 Modeling Local and Global Work Environments

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

- Mimicking Mirroring or getting access to computing technologies in the work environment,
- Preparing students o work in project teams,
- Teaching the concepts of cultural intelligence and social responsibility,
- Providing significant project experiences.

These curricular aspects help model significant issues in the local and international work environment. Faculty can discuss and have students apply international, intercultural, social, and workplace issues within the context of computing resources, teamwork, and projects.

Because computing technologies change rapidly, it is not possible to predict the exact technology that students will work with upon graduation. As a result, it is not advisable to focus attention in the curriculum on a specific technology. Exposure to a wide variety of computing technologies 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 management, communication skills, the characteristics of well-functioning and malfunctioning teams, and sources of stress for team environments.

Educators 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 develop IT competencies.

3.3.3 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.

3.4 Incorporating Professionalism and Ethics into the Curriculum

The incorporation of professionalism and ethics 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, test documents, project documents such as charters and project reports.

Additional material such as computer history, digital libraries, techniques for tackling ill-defined problems, teamwork with individual accountability, real-life ethical issues, professional 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 professionalism and ethics 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 appropriate assessments.

For departments with adequate numbers of faculty members and resources, courses dedicated to teaching professional practice may be appropriate. If resources are limited, this content should be covered in courses like professional practice, ethics, and computer law, as well as senior capstone and other appropriate courses. Additionally, more advanced courses on project management, financial management, 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.

3.5 Assessing Professional and Ethical Work

Learning environments that support students in acquiring professional practice competencies include the following elements:

- Competency-based assessments
- Appropriate inclusion of professional practice in traditional course assessments (assignments, projects, exams, presentations, reports, etc.)
- Sound measurements of student work to show student progress and improvement
- Student involvement in the review and assessment process
- Participation of professionals from industry, government, or other employers of IT graduates to assess student performance in internships, co-op programs, and on projects with outside clients
- Standardized tests validated by professional societies

- Post-graduation alumni surveys of alumni to see how well alumni thought their education prepared them for their careers
- Program accreditation to demonstrate compliance with certain educational standards for professional practice
- Course labs that meet employer needs to make sure students acquire professional competencies.

The assessment process should encourage students to employ good technical practice and high standards of integrity and ethics. 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.

3.6 Certifications

The task group acknowledges the value of vendor and industry certifications and encourages students to pursue them as they see necessary. Programs that offer academic credit for the completion of such certifications or for preparation exclusively designed for these certifications must ensure the technical knowledge gained also maps to all relevant competencies defined in this document. Institutions that offer certification preparation must also ensure that the instructors have the credentials to teach within an institution of higher learning. Many vendor-specific certifications are practice-oriented and highly technical in nature, and complement theoretical understanding, core concepts, computing practices, and IT learning experiences in an IT program curriculum. Therefore, institutions must ensure that the content meets the competencies necessary for a university degree in information technology.

Chapter 4: Competencies and Information Technology

The IT2017 task group has discussed the nature of student learning within the computing profession. It has concluded that graduates from information technology programs require much more than knowledge to be successful practitioners and researchers in information technology. IT graduates must "do" or "perform" activities expected of them such as system integration, cloud security, or API-based architecture development. These activities require development of skills and dispositions through deliberate practice in an authentic context to demonstrate proficiency in IT learning. That is, to become successful IT practitioners and researchers, graduates must demonstrate competencies. This chapter explores the meaning of competencies in an IT context and their relationship with an IT curricular framework.

4.1 Competency in Theory

4.1.1 Meaning of Competency

The literature abounds with clear definitions of learning outcomes [Har1, She1, Ada1, Ken1, Las1]. The learning outcome concept is key to the shift in education from a paradigm concerned with providing instruction to a paradigm of producing learning [Bar1]. The learning outcome concept focuses on the achievements of the learner rather than the intentions of the teachers, as shown in the definition below (adapted from [Ken1, p. 5]:

> *Learning outcomes* are written statements of what a learner is expected to know and be able to demonstrate at the end of a learning unit (or cohesive set of units, course module, entire course, or full program).

In contrast, with the wide agreement on the meaning of learning outcomes, there is extensive confusion and vagueness around the terms competence and competency. Despite the lack of a precise definition, the terms appear to be useful in bridging the gap between education and professional readiness and preparation [Nas1]. Generally, the term competence refers to the performance standards associated with a profession or membership to a licensing organization. Assessing some level of performance in the workplace is frequently used as a competence measure, which means measuring aspects of the job at which a person is competent. Competencies are what a person brings to a job conceptualized as qualities by which people demonstrate superior job performance [Kli1].

There is general agreement in education that success in college and career readiness requires that students develop a range of qualities [Ken1, Nas1, Nrc1], typically organized along three dimensions: knowledge, skills, and dispositions. We propose a working definition of *competency* that connects knowledge, skills, and dispositions. Figure 4.1 (adapted from [Ccs1, p. 5]) shows these interrelated dimensions of competency.

COMPETENCY = KNOWLEDGE + SKILLS + DISPOSITIONS

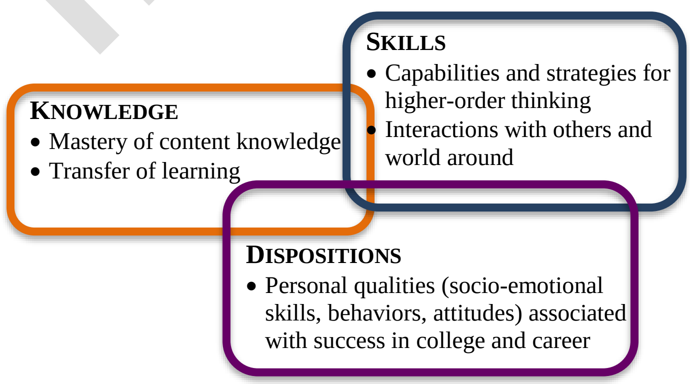

Figure 4.1 Interrelated dimensions of competency

This triadic model of competency helps us avoid perpetuating the practice of preponderantly using the knowledge lens and centering curriculum guidelines on the body of knowledge of IT. Recent ACM computing curricula reports for IT associate degree programs [Acm1] and graduate programs in information systems [Joi2] have also adopted a competency model approach. In our working definition of competency, the three interrelated dimensions have the following meanings.

- *Knowledge* designates a proficiency in core concepts and content of IT and application of learning to new situations. This dimension gets usually most of the attention from teachers, when they design their syllabi, from departments, when they develop program curriculum, and from accreditation organizations, when they articulate accreditation criteria. When asked what an IT course is about or what the requirements of an IT program are, the most pervasive response has a list of topics or courses. Selecting, organizing, and communicating curricular content continue to be the easiest tasks in curriculum development.

- *Skills* refer to capabilities and strategies that develop over time, with deliberate practice and through interactions with others and the world around us [Nrc1]. Skills also require engagement in higher-order cognitive activities, meaning that "hands-on" practice of skills join with a "minds-on" engagement. The inextricable connection between knowledge and skills is evident in Michael Polanyi's characterization of explicit versus tacit knowledge [Pol1]. Explicit knowledge, or "know-that", reflects core ideas and principles, and corresponds to the knowledge dimension in our definition. Tacit knowledge, or "knowhow", is a skillful action requiring sustained engagement and practice. Problem-based assignments, real-world projects, and laboratory activities with workplace relevance are examples of curriculum elements that focus on developing skills. Well-designed syllabi and accredited programs are mindful of skill development when they articulate student outcomes at course and program level.

- *Dispositions* encompass socio-emotional skills, behaviors, and attitudes that characterize the inclination to carry out tasks and the sensitivity to know when and how to engage in those tasks [Per2]. Originating from the field of vocational education and research on career development, dispositions have received increasing attention in the K-12 computer science education community [Ste1]. Formulating an operational definition of computational thinking, Barr and Stephenson [Bar2] included the dispositions category to capture areas of values, motivation, feelings, stereotypes, and attitudes such as confidence in dealing with complexity, tolerance to ambiguity, persistence in working with difficult problems, and knowing one's strengths and weaknesses and setting aside differences when working with others. To distinguish dispositions from knowledge and skills, we use Schussler's view that a disposition "concerns not *what* abilities people have, but *how* people are disposed to use those abilities" [Sch1].

4.1.2 A Performance Perspective on Learning

A transmission theory of teaching, also known as teacher-focused, holds that knowledge emerges as it transmits from the expert teacher to the inexpert learners with the objective of 'getting it across' or covering all the topics in the material. The opposing theory of active learning is that students themselves create meaning and develop understandings with the help of appropriately designed learning activities. In undergraduate education, the active learning model underlies a shift of the paradigm that has governed higher education institutions. The traditional paradigm of *providing instruction* dominated by a passive lecture-based learning environment has shifted to *producing learning* and creating experiences in which students are active participants in the learning process [Bar1].

On a student learning continuum from passive (attending a standard lecture) to active (engaged in problem solving with peers), to produce high level of student engagement means to design learning activities in which students do more than taking notes, recalling, observing, or describing. They learn more effectively when their active participation consists of asking questions, applying concepts, discovering relationships, or generalizing a solution to new situations [Big2]. Higher level of engagement cannot be encouraged if teaching is only about declarative and procedural knowledge: factual information, vocabulary, basic concepts, basic knowhow, and discrete skills [Wig1]. Indeed, students need the acquisition of knowledge and development of basic skills, but this is just a means to a more important preparation for authentic performance tasks and transfer of leaning in new situations.

The highest levels of mastery learning that students should demonstrate by the end of a course or degree program are performance-related. Perkins (1993) and Blythe (1998) formulated a "performance perspective" of learning and offered the view that "understanding something is a matter of being able to carry out a variety of performances concerning the topic" [Per1, Bly1]. A performance perspective of learning requires a "modicum of *transfer*, because it asks the learner to go beyond the information given" and seeks to "… transcend the boundaries of the topic, the discipline, or the classroom".

4.1.3 Learning Transfer

The conventional way of framing curriculum guidelines for undergraduate computing programs is content driven. A disciplinary body of knowledge decomposes into areas, units, and topics to track recent developments in rapidly changing computing field. For this report, the task group proposes to use the *Understanding by Design* (UbD) framework [Wig1] to transform the content-based curricular model of the IT2008 report into a competency-based IT curricular framework. We note that the Computer Science Principles Framework also uses the UbD framework [Col1] for developing courses approved by the College Board to prepare students for the new Advanced Placement in Computer Science examination. The idea of the UbD framework is to treat content mastery as a means, not the end, to long-term achievement gains that a program of study envisions for its graduates. Learners could know and do many discrete things, but still not be able to see the bigger picture, put it all together in context, and apply their learning autonomously in new situations.

Transfer of learning from a classroom environment to the workplace and everyday environments is the ultimate purpose of school-based learning [Bra1]. In the UbD framework, learning transfer is multi-faceted as shown in Table 4.1 [Wig2]. We note that these facets of learning transfer blended skills and dispositions. Explain, interpret, apply and adjust are skills complemented by dispositions related to showing empathy, perceiving sensitively, recognizing bias, considering various points of view, or reflecting on the meaning of new learning and experiences. Dispositions relating to metacognitive awareness include being responsible, adaptable, flexible, self-directed, and self-motivated, and having self-confidence, integrity, and self-control. They also include how we work with others to achieve common goal or solution.

Table 4.1: Six facets of learning transfer (adapted from Understanding by Design framework)

Explain	Learners make connections, draw inferences, express them in their own words with support or justification, use apt analogies; teach others
Interpret	Learners make sense of, provide a revealing historical or personal dimension to ideas, data, and events; interpretation is personal and accessible through images, anecdotes, analogies, and stories; turn data into information; provide a compelling and coherent theory
Apply	Learners use what they have learned in varied and unique situations; go beyond the context in which they learned to new units, courses, and situations beyond the classroom
Demonstrate Perspective	Learners see the big picture, are aware of, and consider various points of view; take a critical and disinterested stance; recognize and avoid bias in how positions are stated
Show Empathy	Learners perceive sensitively; can "walk in another's shoes"; find potential value in what others might find odd, alien, or implausible
Have Self-Knowledge	Learners show metacognitive awareness on motivation, confidence, responsibility, and integrity; reflect on the meaning of new learning and experiences; recognize the prejudices, projections, and habits of mind that both shape and impede their own understanding; are aware of what they do not understand in a particular context.

IT job ads frequently list dispositions as highly desirable by employers such as being enthusiastic, innovative, energetic, self-starter, respectful, or resilient. Inculcating dispositions and inspiring "the ongoing desire to act" responsibly or confidently, for example, comes close to building character [Cle1]. Teachers and curriculum developers should think much harder about how to design learning environments conducive of forming dispositions associated with success in college and careers.

4.2 IT Competencies and Professional Practice

Tyler's hugely influential book *Basic Principles of Curriculum and Instruction* [Tyl1] is a standard reference on ways to develop a dynamic and modern curriculum that supports producing learning rather than merely providing instruction. Integral to curriculum development are learning outcomes, teaching and learning activities, and assessments of student learning. The basis for constructing a curriculum that is competency-driven is to align learning outcomes, activities, and assessments [Big1, Dia1].

On a practical, operational level, we conceptualize competencies as higher-level learning outcomes linked to performance tasks and are descriptive of the professional context of those tasks. We follow Van der Klink and Boon advice that the "fuzziness" of competencies "disappears in the clarity of learning outcomes" [Kli1]. A sensible method to articulate competencies is to select learning outcomes that lead to achieving those competencies along with evaluation indicators suggestive of a professional context [Ken2]. A performance perspective on learning [Per1] is not possible without performance-based assessments. The design of performance assessments considers authentic situations and aspects of work that professionals encounter and through which they demonstrate expertise. Thus, a promising practice to implement a competency-based curriculum is to identify and link the curriculum to professional contexts.

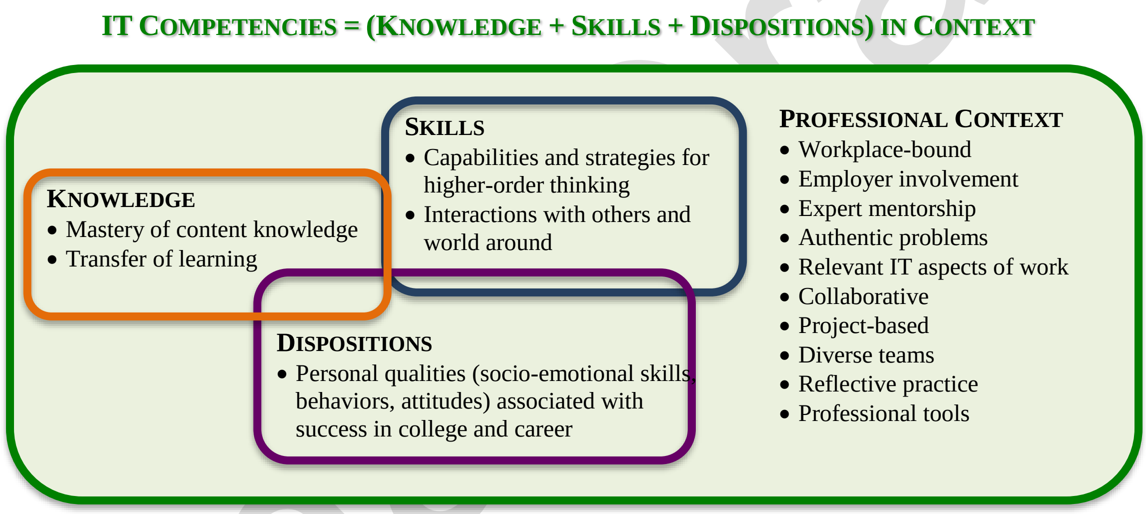

Figure 4.2 IT competency model

The task group's operational definition of IT competencies connects knowledge, skills, and dispositions in a professional context (Figure 4.2). Key characteristics of the IT professional context outline the importance of the following:

- Workplace-bound experiences and relevant IT aspects of work
- Active involvement of employers to support internship and co-op programs and provide expert mentorship
- Authentic problems and engagement of diverse team
- Collaborative and project-based activities leveraged by using professional tools
- Deliberate and critical reflection on practice to participate effectively in decision-making and stay engaged in a process of continuous learning.

Answering quiz questions correctly and performing drills skillfully are very simplified means of achievement as they indicate command of facts and basic knowhow. Examples of learning environments that create professional contexts are practicum and internship experiences, projects with real clients, reflective journals of individual contributions to a complex team project, technical presentations judged by external partners, and capstone/senior projects with external evaluators. These examples can be adapted and expanded based on institutional priorities, circumstances, resources, and expertise that are specific to individual IT programs.

A competency-based approach to an IT curricular framework considers the long-term goal of learning to *achieve genuine competence through ongoing transfer* of what students learn through college and graduates develop in their professions and advanced academic studies. The result of using a competency-based approach to develop an IT curricular framework is to rethink the IT curricular domains in the context of performance goals. To articulate performance goals for each IT domain the task group recommends the UbD approach of considering performance verbs associated with the six facets of learning transfer: explain, interpret, apply, demonstrate perspective, show empathy, and have self-knowledge as described in Table 4.1. A sample list of performance verbs that generate ideas for performance goals and professional practice [Wig2] appears in Chapter 6; they are useful in describing the IT competencies expected from IT graduates.

By focusing on competencies, academic departments become intentional about forging working collaborations with participating employers who share their expertise and have the capacity to engage students in professional practice experiences. The following chapter delves in a comprehensive analysis of how industry perspectives shape a competency-based curricular framework.

Chapter 5: Industry Perspectives on Information Technology

The field of information technology (IT) continues to develop, morph, and expand in its importance to the world economy. 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 relay on computing to automate or drive their products or services efficiently. While Chapter 3 addresses the overall professional viewpoint on information technology, this chapter focuses on industry perspectives of the field.

5.1 Overview of Industry and Information Technology

People seeking careers in IT have a great potential for success, if they possess relevant skills. A recent study by the Bureau of Labor Statistics (BLS) estimates that by 2024 employment in IT in the United States will increase by 12% [Bls1], with information security leading by 36.5% [Bls2]. Employment growth for information security analysts projected for 2014-2024 is 18%. Other computing occupations have larger projected growth: application software developers (19%), computer systems analysts (21%), and web developers (27%). The average growth rate for all occupations is 7 percent. The 36% for information security is the percent change in employment in the computing industry (what BLS calls "Computer Systems Design and Related Services"), rather than across all industries. Web developer occupations have a larger projected growth in the computing industry of 39%. Additionally, large differences exist in the number of jobs each occupation had in 2014. Figure 5.1 addresses these data.

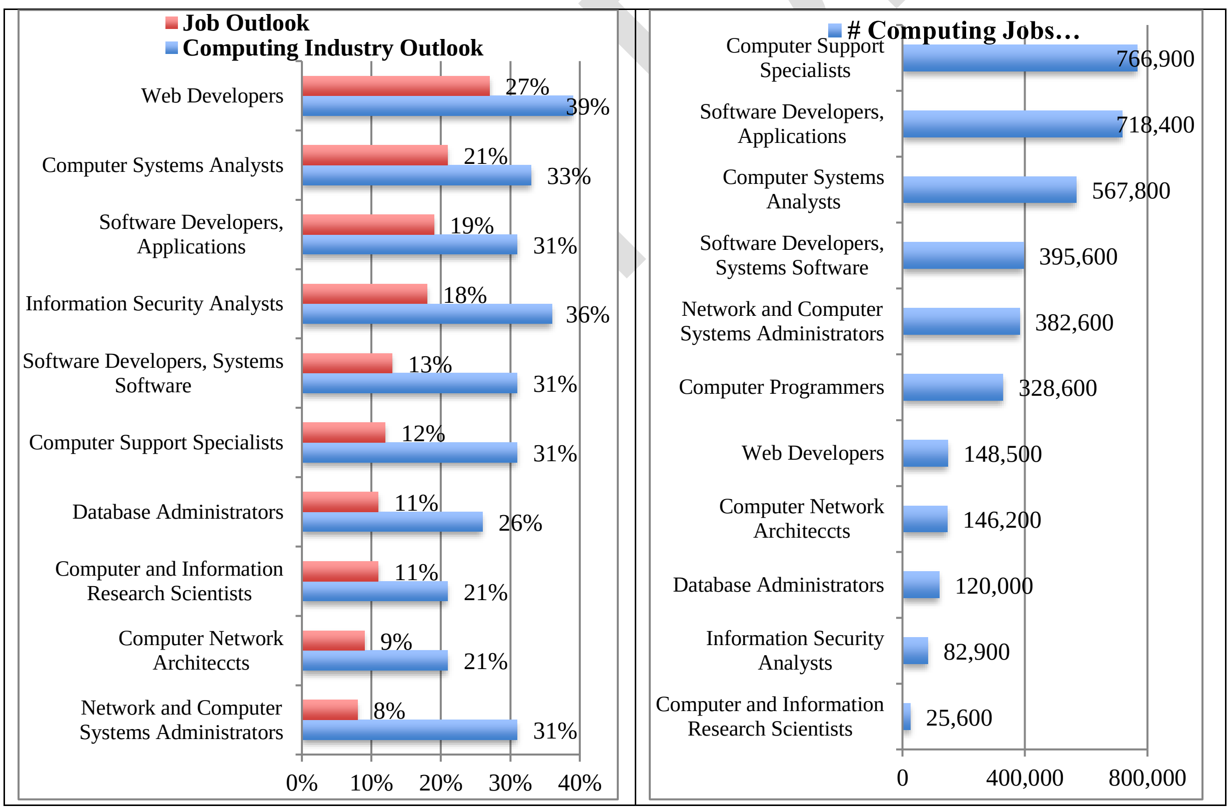

Figure 5.1: Left: Computing occupations projected growth 2014-2024 across all sectors (job look) and in the computing sector. Right: Computing jobs in 2014.

Unfortunately, although jobs are and will be available, employers find it increasingly difficult to find qualified people to fill them. 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. In other cases, individuals may possess typical technical skills, but do not have a grasp over more complex analytical and troubleshooting skills.

5.1.1 The Academic Myth

Students who graduate from a university program assume that the baccalaureate degree is a sufficient qualification to attain a position. This understanding may be true in some fields, but belief in this myth has stymied many job hunters 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 often 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 belief also has challenges. 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.

5.1.2 State of IT Skills Gap

Technical associations tend to focus on industry standards that fosters skills development and that provides vendor-neutral IT certifications globally [Cpt1]. One such organization considers four important areas of the IT field to be:

- *Infrastructure*: Jobs that include network management, project management, help desk and service desk, as well as managing cloud implementations.
- *Development*: Programming and software development for Internet of Things (IoT), mobility, and cloud devices.
- *Security*: Jobs that focus on ensuring that systems are less susceptible to attacks.
- *Data*: Job roles that focus on database management, as well as analytics of stored data.

These areas provide a vision of the job categories available in IT [Cpt2].

Furthermore, there is an increasing reliance on IT workers to help drive organization growth and workplace efficiencies. In an online global survey among 1,507 IT and business executives, CompTIA reports "…68% rate technology as important or very important to business success, and this rate is projected to rise" [Cpt3, p. 5]. Technology has become a key enabler of innovation and organization growth, and technology trends are now driving changes in organizations. McKinsey & Company has forecast the need for over 40 million additional college-educated workers, as well as 95 million workers globally with needed technology skills [Ols1]. A variety of technical skills are desired, as well as technical support, customer service, project management, troubleshooting, problem solving, teamwork/ collaboration and the ability to build effective relationships. Because of the high demand for IT professionals, a global IT Skills Gap has resulted and it should continue and accelerate into the future.

The need for these skills highlights the fact that "… a mere 20% of today's workforce has the skills needed for 60% of the jobs that will be coming online within the next five to ten years" [Hbr1]. Because of this critical situation, academia and industry both realize that an emphasis on developing and preparation workers with these skills is critical. Additionally, statistics from April of 2015 show that an overwhelmingly majority (93%) of HR managers find filling IT jobs difficult or challenging [Cpt4, p. 4]. Figure 5.2 reflects the global impact of this IT skills gap as of February 2015, [Cpt3, p. 45].

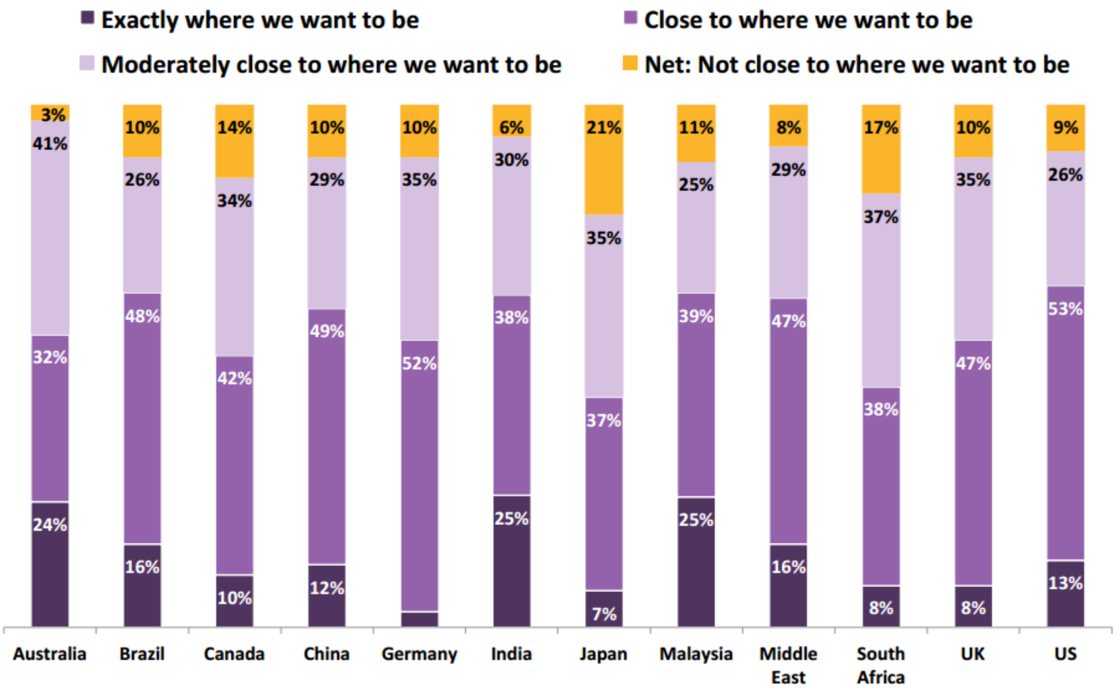

Figure 5.2: Staff IT Skills v. Organization Need by Country (Courtesy of CompTIA)

In addition to gaining a workforce with needed technology skills, the importance of non-technology skills for these jobs makes the task of recruitment even more daunting. A research study in conjunction with employment analytics and labor market information firm, Burning Glass, concludes that "higher paying labor markets and firms demand higher levels of cognitive skills and social skills from their employees…as well as… more productive firms –have greater demand for cognitive skills and social skills" [Dem1]. There is a global competition for IT skill sets. Figure 5.3 illustrates the challenges organizations face in filling openings with the right candidates [Cpt4, p. 8]. The elusive technical and non-technical skills are important components of this scenario.

Challenges Organizations Face in Filling Openings with the Right Candidates	Overall	Small 5-99 employees	Medium 100-499 employees	Large 500+ employees
Finding candidates with the right level of experience	44%	35%	45%	57%
Finding candidates with the right "hard" skills	37%	31%	30%	52%
Pool of quality candidates in the local region	37%	32%	37%	43%
Filling openings in a timely manner	37%	24%	40%	53%
Finding candidates in the right salary range	36%	28%	29%	53%
Finding candidates with the right "soft" skills	36%	31%	27%	49%
Competing with large employers that can make more enticing offers	33%	29%	32%	41%
Costs associated with recruiting (e.g. job board fees, headhunters)	32%	28%	35%	35%

Figure 5.3: Hiring challenges for large corporations (Courtesy of CompTIA)

5.1.3 IT Job Situation

There is a lucrative and robust job market for IT graduates who have the combination of technical and non-technical skills that industry finds essential. The Bureau of Labor Statistics estimated in 2013 that between then and 2020, employment in the computer information and technology sector will increase by some 22 percent, outpacing the wider economy 's 14% percent growth [Ins1].

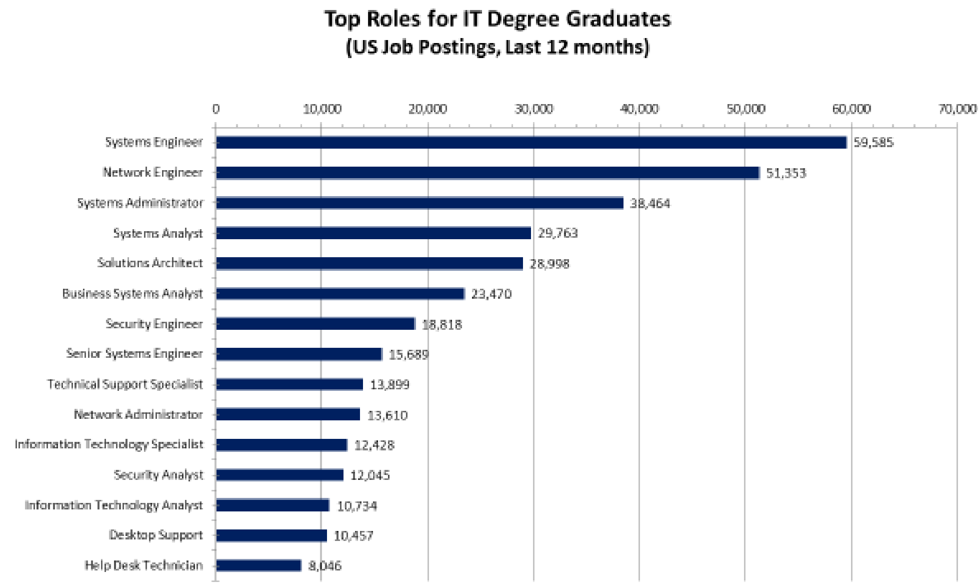

Figure 5.4: Market for top IT degrees [2015] (Source: Burning Glass Technologies)

As reported in Figure 5.4 [Bgl1] and Figure 5.5 [Bgl2] by Burning Glass, the top jobs for IT grads are Systems Engineer, Network Engineer, Systems Administrator, Systems Analyst, Solutions Architect, Business systems Analyst, and Security Engineer. They also indicate that the fastest growing IT Skills include IOT, Docker software, Oracle Cloud, DevOps and Cybersecurity, among others.

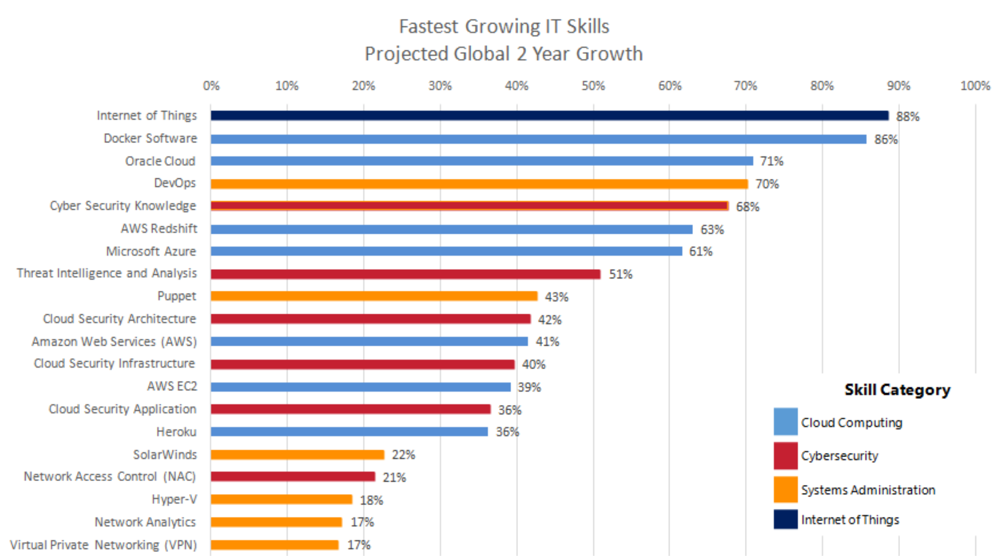

Figure 5.5: IT graduates in an evolving market [2014-2015] (Source: Burning Glass Technologies)

5.2 General IT Skills

There are a wide variety of IT skill sets that are fundamental for those in the IT profession. This section covers a variety of issues related to "soft" skills, communication skills and teamwork skills. Recent research defines more precisely these terms via interviews and surveys with thousands of software engineers and engineering managers [Lip1]. Those who possess most in demand technical skills and non-technical skills (also known as baseline skills) will likely find lots of employment opportunities. Figure 5.6 highlights the technical and non-technical skills in greatest demand from a 201X study relevant to the information technology workplace [Bgl3].

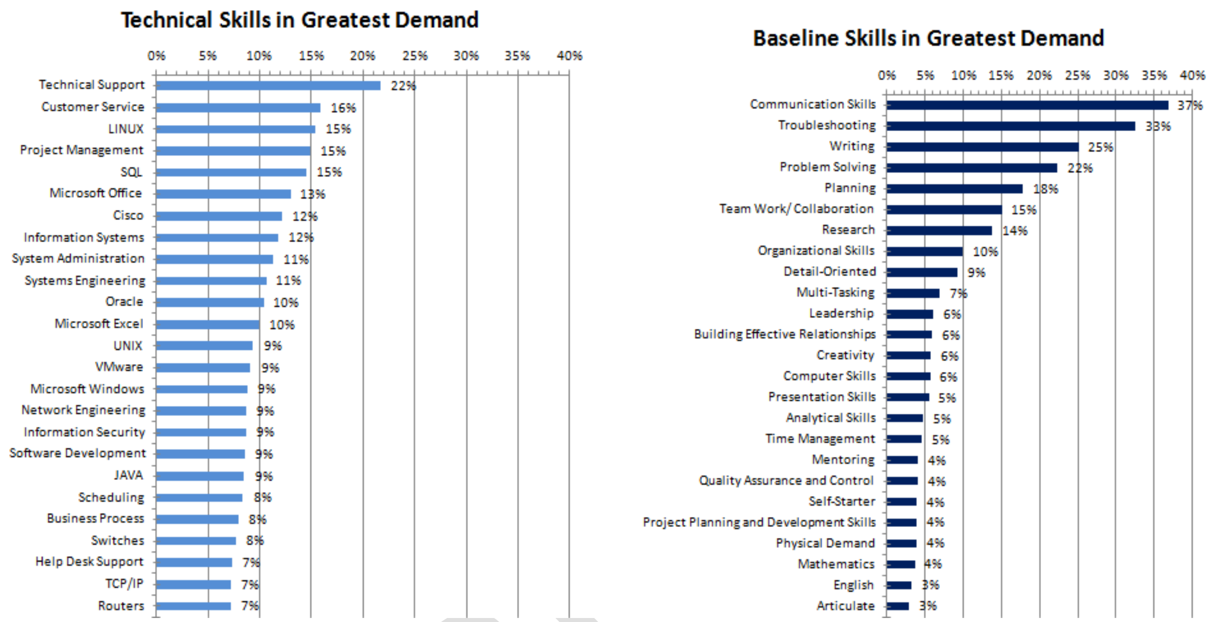

Figure 5.6: Technical and non-technical (baseline) skills as of 2015 (Source: Burning Glass Technologies)

5.2.1 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 non-technical 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* [Dic1].

Another definition indicates that soft skills are the:

> *Character traits and interpersonal skills that characterize a person's relationships with other people* [Inv1].

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].

Note that in this context, soft skills may have other nomenclatures as "workplace" or "professional" skills. Examples of soft skills may include time management, proper and non-disruptive mannerisms, task completion, contribution toward a common cause, and an ability to give and accept feedback.

In the field of information technology and other fields, soft skills often complement technical 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. Examples of soft skills include customer service, teamwork, project management, flexibility, problem solving, motivation and adaptability, building effective relationships, and time management. Figure 5.7 shows the importance of soft skills by country or region [Cpt3, p. 53]. Section 5.4 provides suggestions for developing this valuable skill set that includes mentoring, internships, and work study programs.

Soft-Skills/Non-Technical Skills	Australia	Brazil	Canada	China	Germany	India	Japan	Malaysia	Middle East*	South Africa	UK	US
Project Management	44%	54%	29%	50%	33%	52%	35%	62%	48%	58%	34%	41%
Customer service	49%	59%	47%	45%	33%	48%	29%	57%	48%	72%	49%	41%
Verbal and written communication skills	35%	31%	29%	34%	25%	32%	19%	58%	26%	54%	29%	34%
Teamwork	46%	50%	57%	45%	52%	54%	24%	72%	34%	66%	49%	49%
Strong work ethic	38%	35%	37%	35%	37%	39%	23%	62%	23%	69%	41%	40%
Motivation and initiative	24%	43%	35%	43%	31%	40%	39%	55%	26%	58%	40%	37%
Flexibility and adaptability	30%	38%	40%	58%	33%	40%	28%	44%	10%	52%	33%	43%
Analytical skills	28%	26%	30%	40%	31%	35%	25%	50%	8%	46%	26%	32%
Innovation/creative problem solving	24%	33%	25%	28%	24%	25%	20%	43%	7%	53%	21%	28%

*Middle East is an aggregation of data from Oman, Saudi Arabia and the UAE.

Figure 5.7: Importance of soft-skills / non-technical skills by country or region (Courtesy of CompTIA)

Universities are well adept to teach IT technical skills; however, they encounter challenges when dealing with non-technical skills – especially soft skills. College and university teachers should make every effort to develop non-technical skills. From an industry hiring perspective, chances are that a candidate with strong soft skills will likely obtain the position.

5.2.2 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 of an unclear message 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 across the curriculum should be an embedded thread throughout the curriculum. Students need to have access to 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.

5.2.3 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” [Dic2]. 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 several IT courses in addition to a possible graduation or senior project. These teams are often homogeneous. That is, only IT students are members of teams solving IT specific problems. Teamwork skills could expand via interdisciplinary opportunities where teams that include IT students and students from other areas of study work together to explore mission or organization challenges beyond IT. Therefore, whenever possible, students from different disciplines should try to work together on IT teams.

5.3 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 6 delineates IT domains that constitute the technical educational foundation of an IT graduate. IT degree programs worldwide should establish relationships with industries to optimize learning of the IT curricular framework are most valuable to those potential employers.

Figure 5.8 illustrates this relationship with a map of the United States showing the location by state and by metropolitan statistical area (MSA) of various IT skill sets [Cpt5]. For example, if an IT program at a university lies within a geographic area that is a major region employing network specialists, they may want to increase the focus of their network applications, since they are able to develop an IT curriculum framework that is most beneficial to local employers.

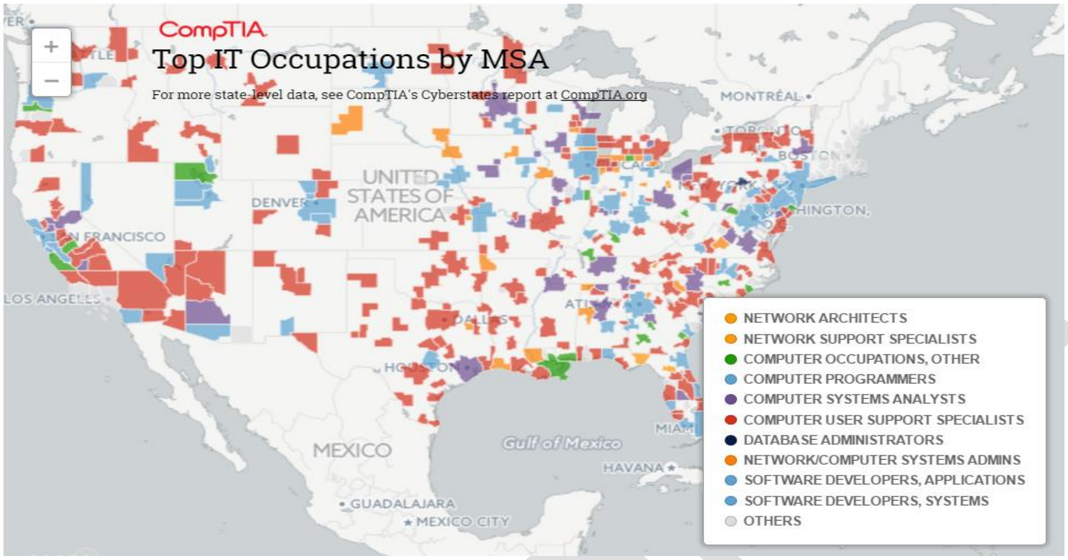

Figure 5.8. Top IT occupations by region (Courtesy of CompTIA)

From an industry perspective, hiring technically competent graduates is important. However, with few exceptions, technical competence may not be as important as the non-technical attributes mentioned earlier such as soft skills, communication skills, and team skills. 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 preparation sessions to achieve the missing skill.

5.3.1 Certification as an indicator of experience

One indicator of experience is IT certification. Individuals who take and pass certification exams can use these credentials to supplement the value of their academic education to potential employers. Educated employees can use certifications to demonstrate their job readiness and pursuit of extra-curricular activities to demonstrate IT skills to potential employers.

Table 5.1 lists leading certifications for 2017 compiled by the CRN media outlet [Nov1]. Readers of this report may find this information useful.

Table 5.1. Common IT Certifications

• Entry-level networking and security (CompTIA, Cisco) • Professional networking and routing and switching (Cisco, Citrix) • Virtualization and networking (Citrix VMWare) • Windows servers and infrastructure (Microsoft) • IT service management (Axelos)	• Project management (Project Management Institute, Axelos) • Security (ISC2) • Security management (ISC2) • Cloud computing (Amazon) • Risk management (ISACA) • IT auditing (ISACA)

As shown in Figure 5.9 [Cpt4, p. 22], certifications also help employers provide a baseline of set of knowledge for certain IT positions; this baseline allows employers to quickly "drill down" to essential skills that they need. Employers also find that IT certifications allow them to choose potential candidates more quickly. As a result, if potential employees have IT certifications, they will find themselves more attractive in the marketplace.

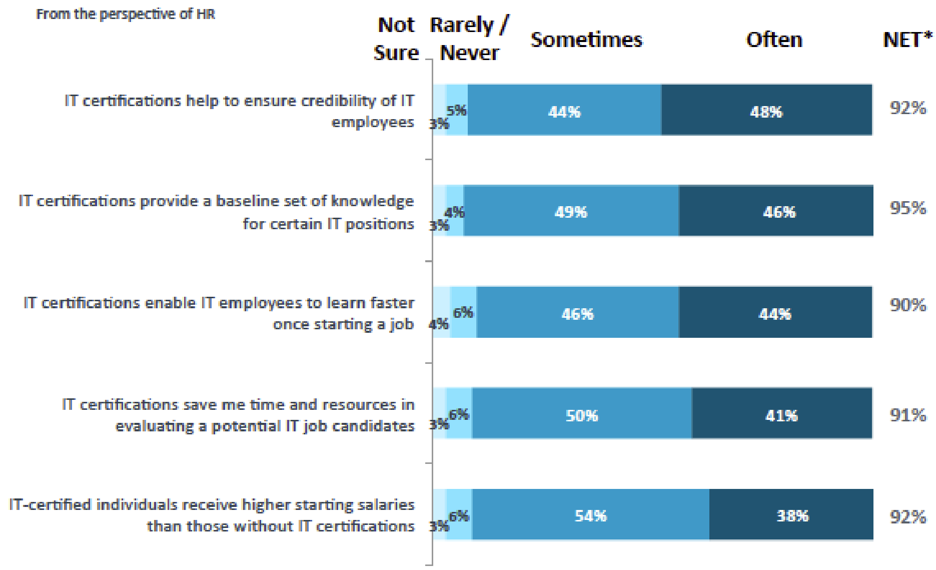

Figure 5.9: Reported benefits of having IT certified job candidates (Courtesy of CompTIA)

Additionally, benefits of certified IT employees include longer retention, higher likelihood of receiving a promotion, and better job performance than non-IT certified staff. It is clear, then, that the IT Industry values certification and education.

5.4 Integrated Skills and Experiential Learning

5.4.1 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 challenged university graduates as they pursue the jobs they desire. One way to mitigate this lack of experience is to encourage students to gain as much hands-on experience as possible. It is not enough to simply attend courses and read books. Hands-on, experiential learning is essential for information technology. Students that "learn by doing" through "live lab" exercises are highly prized.

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 industry employment upon graduation. These experiences are also important in developing those important soft or professional skills that are so valuable in the workplace. Strong IT programs make it possible for students to apply what they have learned. Internship programs are ideal ways to help students further assess their knowledge and implement the skills they have learned.

5.4.2 Academic/Workplace Collaboration

Is the academic community embracing the need for hands-on work opportunities for its students? During the 2016 ITiCSE conference, a poster on “Industry Perspectives and the IT2017 Report” received consideration. To draw attention to the importance of academic/workplace collaborations, the poster contained some of the key findings of the industry survey, conducted in the summer of 2015 for the IT2017 report. In conjunction with the poster presentation, conference attendees completed a short two-question poll to determine if they offered any formal (for credit) collaborations with industry or government such as internships, co-op programs, advisory boards, or full- or part-time jobs. Respondents were from 37 countries and reflected a global perspective of IT. The conference had 165 attendees and 87 persons filled out the poster survey – a 53% response rate. The highest participation for the survey was from the United States, followed by Peru, Australia, and the United Kingdom. See Figure 5.10 for a country distribution.

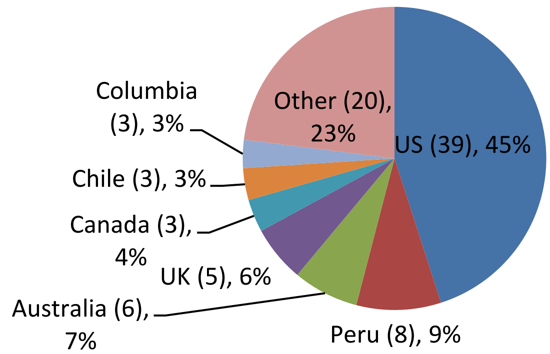

Figure 5.10: Respondent distribution for the ITiCSE conference survey.

For the survey, choices in ways universities collaborate with government or industry employers reflected the percent of respondents who voted for each item. Figure 5.10 shows the collaboration of choices by employer rank among eight items (from highest to lowest).

In response to the question on types of collaborations, the most popular type of collaboration was internships (68%) followed by mentoring (37%), followed by part-time jobs (29%). The survey showed 26% benefited from expertise in teaching courses. Figure 5.11 shows the distribution of responses. Clearly, academia is encouraging and facilitating the need for IT students to gain real-world experience within the field.

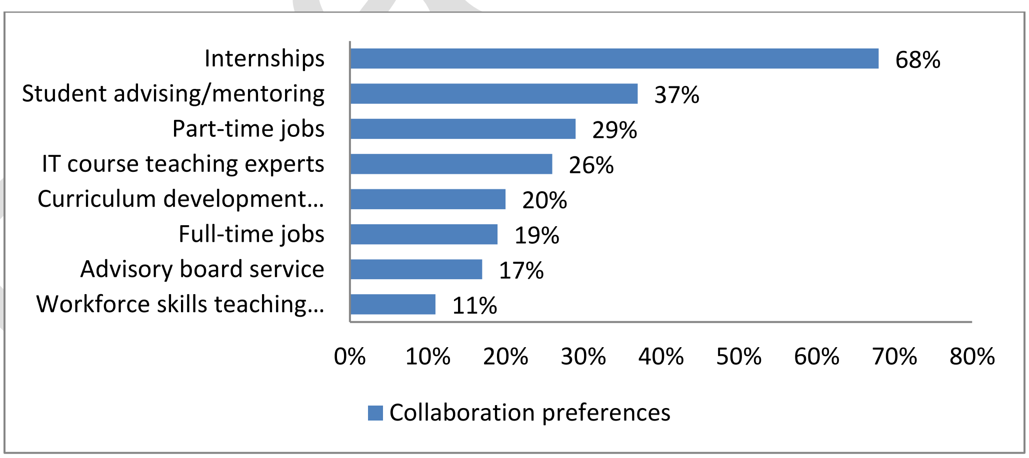

Figure 5.11: Responses to the 2016 ITiCSE survey

5.4.3 The Drive for Experience

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 professional experience gap between academia and industry. Developing a robust industry connection should always be a priority. For example, developing strong professional advisory boards 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. Academics should work with potential employers to be able to differentiate their graduates as having the 'mission-critical' or commercial product specific skills needed.

5.4.4 Closing the IT Skills Gap

Basic skills needed in today's workplace include security analytics, general cybersecurity, and project management. In an analysis of recent United States Bureau of Labor Statistics data, information security analysts saw an 8% bump in growth over the first three months of 2016. More specific security-oriented jobs are also in demand. The security analyst job role is one example. The Bureau of Labor Statistics predicts that information security analysts will be the fastest growing job category, with 18% overall growth between 2012 and 2024. This makes the job role of security analyst the number one fastest growing job in the history of the BLS. As you can see, this increase is not expected to be a short-term "bump." It is a major trend.

A significant skills gap exists in these areas, and others. For example, 68% of employers polled found that it was very challenging for them to hire the right candidates for available jobs (HR Perceptions, 7). One of the primary ways to address this skills gap is IT certification. These certifications use direct input from IT experts from around the world. Such certifications can help academic institutions worldwide focus on teaching basic technical skills. Consequently, 57% of IT directors around the world mandate or recommend IT certifications for employees (HR Perceptions, 13).

5.4.5 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. Approximately 22% were from IT departments of 100 or more persons. The survey produced some interesting results, which we now summarize.

The survey indicated 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.

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 non-technical skills followed in second and third place at 73% and 64%, respectively. One-third of the respondents to the industry survey indicated their willingness to volunteer and help implement the guidance in this document. 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 non-technical 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 5.2 and 5.4. Project managers often receive greater recognition more for these qualities than for their technical skills. Industry thinking is that an adaptive individual can learn any required technical skills. Figure 5.12 shows the technical and organization skills needed as of early 2017 [Cpt6]; it is interesting to contrast these data with those shown in Figure 5.6.

Technical Skills	Needed at Company
Security	40%
Database/Information management	38%
PC support	36%
Storage/Backup	33%
Networks	31%
Cloud architecture	29%
Telecommunications	27%
Web development	27%
Server/Datacenter management	27%
Mobile device support	24%
Application development	23%
Big Data tools/analytics	23%
Virtualization	21%

Business Skills/Soft Skills	Needed at Company
Flexibility	41%
Analytical skills	39%
Teamwork	37%
Customer service	34%
Innovation/Problem solving	33%
Project management	30%
Strong work ethic	29%
Motivation	28%
Business understanding	27%
Broad technology knowledge	27%
Verbal/written communication	22%

Figure 5.12: Range of IT skills needed in 2017 (Courtesy of CompTIA)

In the real world, many examples occur that demonstrate the need for interpersonal, team and communication skills. For example, regarding developing software, industry often complains about the lack of durability in software education, particularly with respect to code enhancement and working with customers.

> *The social skills needed to work effectively with nontechnical customers and work well in teams surely are helpful for the developers' whole careers* [Fox1].

As another example, ING, a Dutch-based banking group, has emulated technology companies, creating a team-oriented, *agile* working environment within its organization. These teams consist of individuals from various areas of the company, all working together to solve client needs. They need to know how to work with a wide variety of persons and departments to reach their goals – a real test of a person's soft skills and ability to work within a team. The benefits from this new technology-emulated organizational structure at ING has generated greater employee engagement, enthusiasm and ultimately productivity, by bringing new software releases to market much more quickly [Jac1].

5.5 Next Steps

Appendix A provides a summary of different technology and informational skills as it appears in a report by the IEEE Computer Society [Cps1]. This *Guide to the Enterprise Information Technology Body of Knowledge* (EITBOK) is a compendium of high-level knowledge areas typically required for the successful delivery of IT services vital to all enterprises. EITBOK defines the key knowledge areas for the IT profession and it embodies concepts recognized as good practice in the IT domain and that are applicable to most IT efforts. The report emphasizes competence on a global scale. Frameworks enable the identification of skills and competences required to perform duties and fulfill responsibilities in an enterprise IT workplace. Among the frameworks discussed are the Skills Framework for the Information Age (SFIA), the European Competency Framework (e-CF), and the i Competency Dictionary (iCD) of Japan.

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 non-technical 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” [Dic3]. 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 and non-technical skill sets as well as industry certifications. Resources such as Monster.com, Dice.com, and Indeed.com are helpful in developing technical resumes.

Being able to handle a successful interview is a career skill that is fundamental for students to practice and to master during 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.

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 fact, further study of business and entrepreneurial courses should provide a better understanding of the relationship between business operations and IT professionals.

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 organizations 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 6: Information Technology Curricular Framework

What follows is a development of an information technology Curricular Framework that defines the competencies IT graduates should master. After much discussion and interaction among the task group members, it became clear that a futuristic proposal of IT competencies should have a broad basis for reference. The IT competencies basis for the IT Curricular Framework in this report draws from the IT discipline itself (Chapter 2), professional practices (Chapter 3), a competency-based approach (Chapter 4), and industry perspectives (Chapter 5) for developing curriculum guidelines. These premises should inform any set of competencies that define a curriculum leading to a modern information technology degree.

6.1 Structure of the IT Curricular Framework

The IT Curricular Framework enables IT departments to implement, evaluate, and revise undergraduate IT degree programs according to their institutional mission and program goals. The framework is organized in IT domains, which collectively represent the scope of IT. It is important to note that an IT domain is ***not*** a course. Mapping IT domains to program course requirements considers factors pertaining to the implementation of the framework, as discussed in the next chapter. The IT domains decompose 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 6.1.4 for more details). A set of competencies and a set of scope statements further describe IT domains Some competencies relate to or are dependent on other competencies. This report does not distinguish such dependencies. For example, problem solving strategies, testing and iterative refinement, and the use of data and procedural abstractions create a learning progression for programming practice.

6.1.1 Essential and Supplemental Domains

One of the goals in this IT2017 report is to keep the implementation requirements of the IT curricular framework as small as possible to allow flexibility for programs in information technology. To implement this principle, a distinction among the IT domains occurs by identifying those that are essential to an IT curriculum compared to those that are supplemental. Essential domains encompass competencies that anyone obtaining an undergraduate degree in the field *must* acquire. Supplemental domains encompass competencies in domains where students do more specialized work according to the goals of a program. Supplemental domains give IT programs more directed choices and flexibility. All degree programs should require students to achieve competencies in some subset of the supplemental domains.

In response to the public comments the IT2017 report received during its development, the report emphasizes the following points.

- The essential domains refer to those competencies that all students in all information technology degree programs must achieve. Several competencies that one might consider important in the education of many students may not appear in the essential classification. This absence among the essential domains does not imply a negative judgment about their value, importance, or relevance to a curriculum. Rather, it simply means that there was not a broad consensus that these domain competencies should be required of every student in all degree programs in information technology.
- The essential domains do *not* produce a complete curriculum. They represent ***minimal*** competencies that must appear in a complete undergraduate IT program.
- Every undergraduate program should include some curricular requirements from supplemental domains in the IT curricular framework. The selection and further expansion of supplemental domains would reflect the purpose and goals of individual IT programs according to the mission of their institutions.
- It is not necessary for a program to implement the essential IT domains within a set of introductory courses early in a program of study. 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 academic background in their studies.

6.1.2 Building the IT Curricula of an IT Degree Program

The IT2017 task group believes that a competent graduate from an undergraduate IT degree program should experience the equivalent of *at least* 1.5 years of information technology studies. For example, in a semester-based IT degree program of 120 credits, one year of study consists of two semesters or 30 credits; one semester consists of 15 credits. Therefore, the IT portion of a curriculum requires 1.5 years of study, which represents *at least* 45 credits or 37.5% of a total curriculum of a 120-credit IT degree program.

The IT2017 task group recommends that IT graduates should achieve all the essential IT domains and that it should be at least 40% of the IT portion of a curriculum in their program of study. In addition, the task group recommends that IT graduates should achieve some of the supplemental IT domains and that it should be approximately 20% of the IT portion of a curriculum in their program of study. The remaining 40% of the IT portion of the curriculum represents other IT requirements that reflect the goals and mission of individual IT degree programs. Figure 6.1 illustrates the structure of the IT portion of a curriculum in an undergraduate IT degree program of 120 credits.

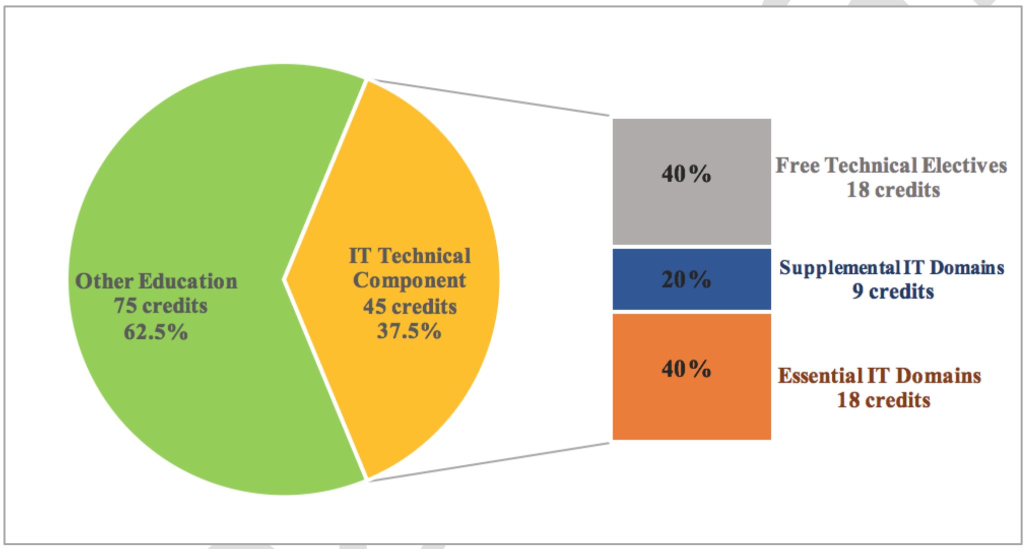

Figure 6.1: Example of the IT portion of a curriculum of an undergraduate IT degree program of 120 credits

Table 6.1 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 percentages associated with each domain relative to the entire IT part of a curriculum in an undergraduate IT degree program.

Table 6.1: IT part of a curriculum with relative percent

IT Domains	Essential Percent	Supplemental Percent
Essential Only		
Information Management	6%	0
Integrated Systems Technology	3%	0
Platform Technologies	1%	0
System Paradigms	6%	0
User Experience Design	3%	0
Subtotal:	**19%**	**0**
Essential + Supplemental		
Cybersecurity Principles / Cybersecurity Emerging Challenges	6%	4%
Global Professional Practice / Social Responsibility	3%	2%
Networking / Applied Networks	5%	4%
Software Fundamentals / Software Development and Management	4%	2%
Web and Mobile Systems / Mobile Applications	3%	3%
Subtotal:	**21%**	
Supplemental Only		
Cloud Computing	0	4%
Data Scalability and Analytics	0	4%
Internet of Things	0	4%
Virtual Systems and Services	0	4%
Subtotal:	**0**	
IT2017 TOTAL:	**40.0%**	

The IT2017 task group already recommended that approximately 20% of the IT part of a curriculum in a degree program should come from the supplemental IT domains. Programs can accomplish this in several ways. For example, a program could choose five, 4% supplemental domains. Another possibility is to take six supplemental domains with relative percentages of: 4%,4%, 4%, 4%, 2%, and 2%. Each IT program should choose the supplemental domains to reflect the goals and the mission of the program.

This report provides a *minimal* framework for implementing an IT curriculum in an undergraduate IT degree program. Strong IT degree programs would have a much stronger IT portion that would exceed 37.5% of the total program curriculum to prepare competent and competitive graduates for IT industries or for graduate studies. In regions or countries where general education occurs in pre-university studies and is not a part of the undergraduate education, the IT portion of the curriculum could even exceed 80% of the degree program.

6.1.3 Level of Learning Engagement

To give readers a sense of student learning of IT competencies in this curricular framework, this report uses a *level system* as an indicator of learning engagement. IT2017 task group defines three levels, L1, L2, and L3 as a measurement of learning engagement for each subdomain in any given IT domain. Ultimately, individual programs determine these levels relative to actual curricular requirements in their programs, pedagogical approaches, and assessments of student learning. Under no circumstances do these levels reflect the importance of any subdomain since every subdomain is important.

We note that L2 level subsumes L1 level and L3 level subsumes L2 level. The inspiration for the proposed level system comes from Jerome Bruner's classic book, "The Process of Education" [Bru1] and the notion of spiral curriculum for "continual broadening and deepening of knowledge." In a spiral curriculum model, learners first engage with central understandings and practices to activate their prior experiences in the context of the current instructional objectives. Second, a spiral curriculum builds on initially learned concepts and practices and further develops them by applying and transferring learning to new problems or settings [Gen1]. Level L1 corresponds to the first function of the spiral curriculum model, and levels L2 and L3 correspond to the second one.

To dispel any potential confusion, it is important to underscore the following observations about the use of level indicators.

- Level L1 (L1) used within a subdomain indicates a minimal degree of engagement associated with the learning proficiency of the fundamentals of the subdomain.
- Levels 2 (L2) and 3 (L3) used within a subdomain indicate medium and large degrees of learning engagement associated with the application and transferring of learning to complex problems and situations. Investigative laboratory activities, prototyping of computational artifacts, authentic projects, public professional presentations, and other authentic performances [Wig3] are examples of L2 and L3-level of learning engagement with the subdomain material. Such learning relates with more time-intensive evaluations that require in-depth and personalized feedback and opportunities for external evaluation from participating employers.

Even though the task group used a relative metric for the level of learning engagement, it strongly believes that instructors should support inquiry, collaborative, and reflective learning and use equity and culturally-responsive pedagogies to engage effectively all students with the IT domain content and practices. Level indicators serve as a comparative metric in the sense that level L3 represent three times the degree of engagement compared to level L1. Of course, this is just an approximation because each program will design its own learning experiences and environments in various formats (face-to-face, online, blended). To ensure program flexibility, the levels indicated for IT subdomains represent a *minimum* degree of engagement. When appropriate it is desirable to engage students more deeply on a curricular subdomain than the recommended minimal level.

6.1.4 Tags for IT Domains

All IT domains contain identifying tags. These tags always contain the prefix "IT_" to distinguish them from other related computing curricula reports. We use "ITE" for essential IT domains, "ITS" for supplemental IT domains, and "ITM" for related IT mathematics. Each IT domain has a three-letter abbreviation such as IOT for representing internet of things or NET for representing networks. As a result, each domain contains 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 representing "virtual systems and services" as a supplemental IT domain, and ITM-DSC for representing "discrete structures" as a mathematical domain related to information technology. The subdomains of each IT domains are numbered. For example, the first two subdomains in ITE-UXD are ITE-UXD-01and ITE-UED-02.

6.2 Distilling the IT Curricular Framework

This section of the report addresses the elements of the curricular framework for information technology. These elements consist of the IT portion of a curriculum (essential and supplemental domains), the related mathematics of a curriculum, and the related science of a curriculum.

6.2.1 IT Portion of a Curriculum: Essential and Supplemental Domains

A summary of the IT curricular framework appears in Tables 6.2. The essential IT domains are in Table 6.2a. The supplemental IT domains are in Table 6.2b. The tables show the IT domains, their subdomains, and the level of learning engagement for each subdomain expressed by level indicator shown in brackets. Tags differentiate the different domains and subdomains. For example,

ITE-IMA-05 Data organization architecture [L3]

indicates that "data organization architecture" should have a large degree of learning engagement as its level is L3; it belongs to the fifth subdomain of the "information management" domain, which is essential for an information technology degree program.

Table 6.2a indicates that a program should select all IT essential domains that accumulate to approximately 40% of the IT portion of a curriculum. In addition, Table 6.2b indicates that a program should select IT supplemental domains that accumulate to approximately 20% of the IT portion of a curriculum.

The IT domains listed in Table 6.2a and Table 6.2b are a result of employer and faculty surveys that task group members analyzed and reported in [Sab2, Sab3] as well as presentations made to information technology communities [Bye1, Imp2, Imp3, Imp4, Sab3, Sab4, Sab5, Sab6, Sab7, Tim1]. The listing is alphabetical according to tag names. The percent for each domain corresponds to the percent of the IT portion as explained in Table 6.1. Nothing in this report prevents an IT program from increasing the breadth and depth of an essential or supplemental domain. IT programs could include new supplemental domains consistent with the goals of their program. In fact, the IT2017 task group encourages such activities.

Table 6.2a: Essential IT domains

Essential IT Domains and Levels of Student Engagement	
ITE-CSP Cybersecurity Principles [6%] ITE-CSP-01 Perspectives and impact [L1] ITE-CSP-02 Policy goals and mechanisms [L1] ITE-CSP-03 Security services, mechanisms, and countermeasures [L2] ITE-CSP-04 Cyber-attacks and detection [L2] ITE-CSP-05 High assurance systems [L2] ITE-CSP-06 Vulnerabilities, threats, and risk [L2] ITE-CSP-07 Anonymity systems [L1] ITE-CSP-08 Usable security [L1] ITE-CSP-09 Cryptography overview [L1] ITE-CSP-10 Malware fundamentals [L1] ITE-CSP-11 Mitigation and recovery [L1] ITE-CSP-12 Personal information [L1] ITE-CSP-13 Operational issues [L2] ITE-CSP-14 Reporting requirements [L1]	**ITE-GPP Global Professional Practice** [3%] ITE-GPP-01 Perspectives and impact [L1] ITE-GPP-02 Professional issues and responsibilities [L1] ITE-GPP-03 IT governance and resource management [L1] ITE-GPP-04 Risk identification and evaluation [L1] ITE-GPP-05 Environmental issues [L1] ITE-GPP-06 Ethical, legal, and privacy issues [L1] ITE-GPP-07 Intellectual property [L1] ITE-GPP-08 Project management principles [L1] ITE-GPP-09 Communications [L1] ITE-GPP-10 Teamwork and conflict management [L1] ITE-GPP-11 Employability skills and careers in IT [L1] ITE-GPP-12 Information systems principles [L1]
ITE-IMA Information Management [6%] ITE-IMA-01 Perspectives and impact [L1] ITE-IMA-02 Data-information concepts [L2] ITE-IMA-03 Data modeling [L3] ITE-IMA-04 Database query languages [L3] ITE-IMA-05 Data organization architecture [L3] ITE-IMA-06 Special-purpose databases [L1] ITE-IMA-07 Managing the database environment [L2]	**ITE-IST Integrated Systems Technology** [3%] ITE-IST-01 Perspectives and impact [L1] ITE-IST-02 Data mapping and exchange [L2] ITE-IST-03 Intersystem communication protocols [L2] ITE-IST-04 Integrative programming [L2] ITE-IST-05 Scripting techniques [L2] ITE-IST-06 Defensible integration [L1]
ITE-NET Networking [5%] ITE-NET-01 Perspectives and impact [L1] ITE-NET-02 Foundations of networking [L1] ITE-NET-03 Physical layer [L2] ITE-NET-04 Networking and interconnectivity [L3] ITE-NET-05 Routing, switching, and internetworking [L2] ITE-NET-06 Application networking services [L2] ITE-NET-07 Network management [L3]	**ITE-PFT Platform Technologies** [1%] ITE-PFT-01 Perspectives and impact [L1] ITE-PFT-02 Operating systems [L3] ITE-PFT-03 Computing infrastructures [L1] ITE-PFT-04 Architecture and organization [L1] ITE-PFT-05 Application execution environment [L1]
ITE-SPA System Paradigms [6%] ITE-SPA-01 Perspectives and impact [L1] ITE-SPA-02 Requirements [L2] ITE-SPA-03 System architecture [L1] ITE-SPA-04 Acquisition and sourcing [L2] ITE-SPA-05 Testing and quality assurance [L2] ITE-SPA-06 Integration and deployment [L2] ITE-SPA-07 System governance [L2] ITE-SPA-08 Operational activities [L3] ITE-SPA-09 Operational domains[L3] ITE-SPA-10 Performance analysis [L1]	**ITE-SWF Software Fundamentals** [4%] ITE-SWF-01 Perspectives and impact [L1] ITE-SWF-02 Concepts and techniques [L2] ITE-SWF-03 Problem-solving strategies [L1] ITE-SWF-04 Program development [L3] ITE-SWF-05 Fundamental data structures [L2] ITE-SWF-06 Algorithm principles and development [L2] ITE-SWF-07 Modern app programming practices [L1]
ITE-UXD User Experience Design [3%] ITE-UXD-01 Perspectives and impact [L1] ITE-UXD-02 Human factors in design [L2] ITE-UXD-03 Effective interfaces [L2] ITE-UXD-04 Application domain aspects [L1] ITE-UXD-05 Affective user experiences [L1] ITE-UXD-06 Human-centered evaluation [L1] ITE-UXD-07 Assistive technologies and accessibility [L1] ITE-UXD-08 User advocacy [L1]	**ITE-WMS Web and Mobile Systems** [3%] ITE-WMS-01 Perspectives and impact [L1] ITE-WMS-02 Technologies [L2] ITE-WMS-03 Digital media [L2] ITE-WMS-04 Applications concepts [L2] ITE-WMS-05 Development Frameworks [L2] ITE-WMS-06 Vulnerabilities [L1] ITE-WMS-07 Social software [L1]

Table 6.2b: Supplemental IT domains

Supplemental IT Domains and Levels of Student Engagement	
ITS-ANE Applied Networks [4%] ITS-ANE-01 Proprietary networks [L2] ITS-ANE-02 Network programming [L2] ITS-ANE-03 Routing protocols [L2] ITS-ANE-04 Mobile networks [L2] ITS-ANE-05 Wireless networks [L2] ITS-ANE-06 Storage area networks [L1] ITS-ANE-07 Applications for networks [L2]	**ITS-CCO Cloud Computing** [4%] ITS-CCO-01 Perspectives and impact [L1] ITS-CCO-02 Concepts and fundamentals [L2] ITS-CCO-03 Security and data considerations [L2] ITS-CCO-04 Using cloud computing applications [L2] ITS-CCO-05 Architecture [L2] ITS-CCO-06 Development in the cloud [L2] ITS-CCO-07 Cloud infrastructure and data [L2]
ITS-CEC Cybersecurity Emerging Challenges [4%] ITS-CEC-01 Case studies and lessons learned [L1] ITS-CEC-02 Network forensics [L2] ITS-CEC-03 Stored data forensics [L2] ITS-CEC-04 Mobile forensics [L1] ITS-CEC-05 Cloud security [L1] ITS-CEC-06 Security metrics [L1] ITS-CEC-07 Malware analysis [L1] ITS-CEC-08 Supply chain and software assurance [L1] ITS-CEC-09 Personnel and human security [L1] ITS-CEC-10 Social dimensions [L1] ITS-CEC-11 Security implementations [L1] ITS-CEC-12 Cyber-physical systems and the IoT [L1]	**ITS-DSA Data Scalability and Analytics** [4%] ITS-DSA-01 Perspectives and impact [L1] ITS-DSA-02 Large-scale data challenges [L2] ITS-DSA-03 Data management [L2] ITS-DSA-04 Methods, techniques, and tools [L2] ITS-DSA-05 Data governance [L2] ITS-DSA-06 Applications [L2]
ITS-IOT Internet of Things [4%] ITS-IOT-01 Perspectives and impact [L1] ITS-IOT-02 IoT architectures [L2] ITS-IOT-03 Sensor and actuator interfacing [L1] ITS-IOT-04 Data acquisition [L1] ITS-IOT-05 Wireless sensor networks [L2] ITS-IOT-06 Ad-hoc networks [L1] ITS-IOT-07 Automatic control [L2] ITS-IOT-08 Intelligent information processing [L2] ITS-IOT-09 IoT application and design [L2]	**ITS-MAP Mobile Applications** [3%] ITS-MAP-01 Perspectives and impact [L1] ITS-MAP-02 Architectures [L1] ITS-MAP-03 Multiplatform mobile application development [L2] ITS-MAP-04 Servers and notifications [L1] ITS-MAP-05 Performance issues [L1] ITS-MAP-06 Views and gestures [L1] ITS-MAP-07 Interface implementations [L2] ITS-MAP-08 Camera, state, and documents interaction [L1] ITS-MAP-09 2D graphic and animation [L1]
ITS-SDM Software Development and Management [2%] ITS-SDM-01 Process models and activities [L2] ITS-SDM-02 Platform-based development [L1] ITS-SDM-03 Tools and services [L2] ITS-SDM-04 Management [L2] ITS-SDM-05 Deployment, operations, maintenance [L2]	**ITS-SRE Social Responsibility** [2%] ITS-SRE-01 Social context of computing [L2] ITS-SRE-02 Goals, plans, tasks, deadlines, and risks [L2] ITS-SRE-03 Government role and regulations [L1] ITS-SRE-04 Global challenges and approaches [L1] ITS-SRE-05 Risk management [L1] ITS-SRE-06 Sustainable Computing [L1]
ITS-VSS Virtual Systems and Services [4%] ITS-VSS-01 Perspectives and impact [L1] ITS-VSS-02 Application of virtualization [L2] ITS-VSS-03 User platform virtualization [L1] ITS-VSS-04 Server virtualization [L1] ITS-VSS-05 Network virtualization [L2] ITS-VSS-06 Cluster design and administration [L2] ITS-VSS-07 Software cluster applications [L2] ITS-VSS-08 Storage [L1]	

6.2.2 Related Mathematics

The IT2017 task group recommends that a robust information technology program should have at least discrete structures (mathematics) and a variety of other mathematical experiences to prepare 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; however, they should include pre-calculus, usually taught in secondary schools or in preparatory programs.

In a manner similar to the IT domains, we partition the mathematics portion of the IT curricular framework into essential and supplemental domains. Table 6.3 depicts a single essential domain with its accompanying subdomains. The supplemental domains consist of selected subjects from college-level mathematics appropriate for the IT discipline. These include but not limited to the following.

- Probability
- Statistics
- Financial modeling
- Data analytics
- Linear algebra
- Calculus

Programs should seek to include as much appropriate mathematics as possible to reflect the goals and the needs of their constituents, so their graduates can achieve success in the workplace or in graduate studies. The IT2017 task group recommends that IT students must achieve the IT essential mathematics domain competencies in addition to the supplemental mathematics. The IT2017 task group also recommends that the mathematics should be at least 10% of an undergraduate IT degree program to prepare a competent and competitive IT graduate.

Table 6.3: Related IT essential mathematics

IT Essential Mathematics and Levels of Student Engagement	
ITM-DSC Discrete Structures	
ITM-DSC-01	Perspectives and impact [L1]
ITM-DSC-02	Sets [L1]
ITM-DSC-03	Functions and relations [L1]
ITM-DSC-04	Proof techniques [L1]
ITM-DSC-05	Logic [L1]
ITM-DSC-06	Boolean algebra principles [L1]
ITM-DSC-07	Minimization [L1]
ITM-DSC-08	Graphs and trees [L2]
ITM-DSC-09	Combinatorics [L1]
ITM-DSC-10	Iteration and recursion [L1]
ITM-DSC-11	Complexity Analysis [L1]
ITM-DSC-12	Discrete information technology applications [L1]

6.2.3 Related Science

The IT2017 task group has chosen not to recommend specific science domains related to IT programs. However, it does recommend that students undertaking an information technology program engage in as much science as appropriate to the goals of the program and the institution. Both employer and faculty surveys favor physics as a suitable choice [Sab3]. The reason for a science recommendation is that students in the technological field should develop strong analytical and critical thinking skills as well as acquire empirical and experimental learning skills. The IT2017 task group also recommends that the science portion of a curriculum should be at least 5% of an undergraduate IT degree program to prepare a competent and competitive IT graduate.

6.2.4 Putting It All Together

Section 6.2.1 discussed the IT portion of a curriculum for an undergraduate information technology degree program. The IT portion consisted of essential IT domains (40%), supplemental IT domains (20%), and other IT curricular requirements (40%). Section 6.2.2 provided the IT mathematics component, while section 6.2.3 provided the IT science component. For example, for an IT program consisting of 120 credits (semester hours) over four years, *at least* 1.5 years of study consists of *at least* 45 credits or 37.5% of the program. The mathematics portion should be *at least* 12 credits (10%) and the science portion should be *at least* 6 credits (5%). Figure 6.2 illustrates the components for an undergraduate information technology degree program. Note that the other curricular requirements could consist of any combination of IT and non-IT subjects reflective of the mission and needs of the program.

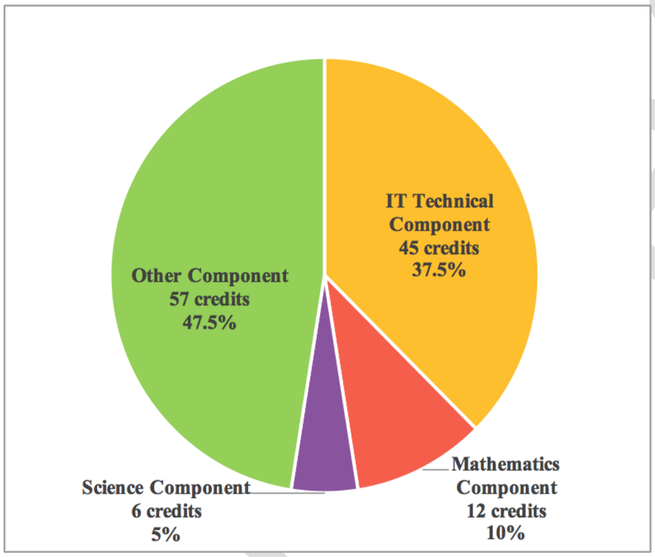

Figure 6.2: A curriculum model for an undergraduate IT program with IT, related mathematics, and related science components

6.3 IT Domain Clusters

The task group has chosen to consolidate the descriptions of IT domains into a set of scope statements, competencies, and subdomains. It calls this consolidation an *IT domain cluster*, identified by an IT domain tag and name.

The competencies that describe learning transfer and performance do not occur in a vacuum. Competencies require proper contexts of authentic workplace-bound experiences that foster employer involvement. Chapter 4 provides a comprehensive discussion of competencies and their use in information technology. It also suggests the use of performance verbs that generate ideas for performance goals and professional practice [Wig2]. These verbs align with six characteristics as shown in Table 6.4. The intent of this table is to be instructive rather than prescriptive. The included verbs represent a few examples on ways to convey learning transfer through application; other active verbs, especially those from non-English settings, could reflect any one of the six characteristics. These characteristics organized by this table anchor the competencies that occur in each IT domain cluster; the verbs represent starting points for describing a contextualized professional practice.

Table 6.4: Performance verbs to generate ideas for performance goals and professional practice

Explain	Interpret	Apply	Demonstrate Perspective	Show Empathy	Have Self-Knowledge
demonstrate	create analogies	adapt	analyze	assume role of	be aware of
derive	critique	build	argue	be like	realize
describe how	document	create	compare	be open to	recognize
design	evaluate	debug	contrast	believe	reflect
exhibit	illustrate	decide	criticize	consider	self-assess
express	judge	design	infer	imagine	
induce	make sense of	exhibit		relate	
instruct	make meaning of	invent		role play	
justify	provide metaphors	perform			
model	read between the lines	produce			
predict	represent	propose			
prove	tell a story of	solve			
show how	translate	test			
synthesize		use			
teach					

Additionally, Appendix B provides a list of suggested performances related to competencies within a given domain. The following subsections present the essential and supplemental IT domain clusters.

6.3.1 Essential IT Domain Clusters

The following descriptions reflect the content of each essential IT domain cluster.

ITE-CSP Domain: Cybersecurity Principles

Scope

1. A computing-based discipline involving technology, people, information, and processes to enable assured operations.
2. A focus on implementation, operation, analysis, and testing of the security of computing technologies
3. Recognition of the interdisciplinary nature of the application of cybersecurity including aspects of law, policy, human factors, ethics, and risk management in the context of adversaries.
4. The practice of assuring information and managing risks related to the use, processing, storage, and transmission of information or data and the systems and processes used for those purposes.
5. Measures that protect and defend information and information systems by ensuring their availability, integrity, authentication, confidentiality, and non-repudiation.

Competencies

A. Evaluate the purpose and function of cybersecurity technology identifying the tools and systems that reduce the risk of data breaches while enabling vital organization practices. (*Cybersecurity functions*)
B. Implement systems, apply tools, and use concepts to minimize the risk to an organization's cyberspace to address cybersecurity threats. (*Tools and threats*)
C. Use a risk management approach for responding to and recovering from a cyber-attack on system that contains high value information and assets such as an email system. (*Response and risks*)
D. Develop policies and procedures needed to respond and remediate a cyber-attack on a credit card system and describe plan to restore functionality to the infrastructure. (*Policies and procedures*)

Subdomains

ITE-CSP-01	Perspectives and impact [L1]	ITE-CSP-08	Usable security [L1]
ITE-CSP-02	Policy goals and mechanisms [L1]	ITE-CSP-09	Cryptography overview [L1]
ITE-CSP-03	Security services, mechanisms, and countermeasures [L2]	ITE-CSP-10	Malware fundamentals [L1]
ITE-CSP-04	Cyber-attacks and detection [L2]	ITE-CSP-11	Mitigation and recovery [L1]
ITE-CSP-05	High assurance systems [L2]	ITE-CSP-12	Personal information [L1]
ITE-CSP-06	Vulnerabilities, threats, and risk [L2]	ITE-CSP-13	Operational issues [L2]
ITE-CSP-07	Anonymity systems [L1]	ITE-CSP-14	Reporting requirements [L1]

ITE-GPP Domain: Global Professional Practice

Scope

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

Competencies

A. Analyze the importance of communication skills in a team environment and determine how these skills contribute to the optimization of organization goals. (*Communication and teamwork*)
B. Evaluate the specific skills necessary for maintaining continued employment in an IT career that involves system development in an environmental context. (*Employability*)
C. Develop IT policies within an organization that that includes privacy, legal, and ethical considerations as it relates to a corporate setting. (*Legal and ethical*)
D. Evaluate related issues facing an IT project and develop a project plan using a cost/benefit analysis including risk considerations in creating an effective project plan from its start to its completion. (*Project management*)

Subdomains

ITE-GPP-01	Perspectives and impact [L1]	ITE-GPP-07	Intellectual property [L1]
ITE-GPP-02	Professional issues and responsibilities [L1]	ITE-GPP-08	Project management principles [L1]
ITE-GPP-03	IT governance and resource management [L1]	ITE-GPP-09	Communications [L1]
ITE-GPP-04	Risk identification and evaluation [L1]	ITE-GPP-10	Teamwork and conflict management [L1]
ITE-GPP-05	Environmental issues [L1]	ITE-GPP-11	Employability skills and careers in IT [L1]
ITE-GPP-06	Ethical, legal, and privacy issues [L1]	ITE-GPP-12	Information systems principles [L1]

ITE-IMA Domain : Information Management

Scope

1. Tools & techniques for efficient data modeling, collection, organization, retrieval and management.
2. How to extract information from data to make data meaningful to the organization.
3. How to develop, deploy, manage and integrate data and information systems to support the organization.
4. Safety and security issues associated with data and information.
5. Tools & techniques for producing useful knowledge from information.

Competencies

A. Express how the growth of the internet and demands for information have changed data handling, transactional and analytical processing, and led to the creation of special purpose databases. (*Requirements*)
B. Design and implement a physical model based on appropriate organization rules for a given scenario including the impact of normalization and indexes. (*Requirements and development*)
C. Create working SQL statements for simple and intermediate queries to create and modify data and database objects to store, manipulate and analyze enterprise data. (*Testing and performance*)
D. Analyze ways data fragmentation, replication and allocation affect database performance in an enterprise environment. (*Integration and evaluation*)
E. Perform major database administration tasks such as create and manage database users, roles and privileges, backup, and restore database objects to ensure organizational efficiency, continuity and information security. (*Testing and performance*)

Subdomains

ITE-IMA-01	Perspectives and impact [L1]	ITE-IMA-05	Data organization architecture [L3]
ITE-IMA-02	Data-information concepts [L2]	ITE-IMA-06	Special-purpose databases [L1]
ITE-IMA-03	Data modeling [L3]	ITE-IMA-07	Managing the database environment [L2]
ITE-IMA-04	Database query languages [L3]		

ITE-IST Domain: Integrated Systems Technology

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

Competencies

A. Illustrate how to code and store characters, images and other forms of data in computers and show why data conversion is often a necessity when merging disparate computing systems together. (*Data mapping and exchange*)
B. Show how a commonly used intersystem communication protocol works, including its advantages and disadvantages. (*Intersystem communication protocols*)
C. Design, debug and test a script that includes selection, repetition and parameter passing. (Integrative programming and scripting)
D. Illustrate the goals of secure coding, and show how to use these goals as guideposts in dealing with preventing buffer overflow, wrapper code, and securing method access. (*Defensible integration*)

Subdomains

ITE-IST-01	Perspectives and impact [L1]	ITE-IST-04	Integrative programming [L2]
ITE-IST-02	Data mapping and exchange [L2]	ITE-IST-05	Scripting techniques [L2]
ITE-IST-03	Intersystem communication protocols [L2]	ITE-IST-06	Defensible integration [L1]

ITE-NET Domain: Networking

Scope	Competencies
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	A. Analyze and compare the characteristics of various communication protocols and how they support application requirements within a telecommunication system. (*Requirements and Technologies)* B. Analyze and compare several networking topologies in terms of robustness, expandability, and throughput used within a cloud enterprise. (*Technologies*) C. Describe different network standards, components, and requirements of network protocols within a distributed computing setting. (*Network protocol technologies*) D. Produce managerial policies to address server breakdown issues within a banking system. (*Risk Management*) E. Explain different main issues related to network management. (*Network Management*)

Subdomains

ITE-NET-01	Perspectives and impact [L1]	ITE-NET-05	Routing, switching, and internetworking [L2]
ITE-NET-02	Foundations of networking [L1]	ITE-NET-06	Application networking services [L2]
ITE-NET-03	Physical layer [L2]	ITE-NET-07	Network management [L3]
ITE-NET-04	Networking and interconnectivity [L3]		

ITE-PFT Domain: Platform Technologies

Scope	Competencies
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	A. Describe how the historical development of hardware and operating system computing platforms produced the computing systems we have today. (*Computing systems)* B. Show how to choose among operating system options, and install at least an operating system on a computer device. (*Operating systems*) C. Justify the need for power and heat budgets within an IT environment, and document the factors needed when considering power and heat in a computing system. (*Computing infrastructure*) D. Produce a block diagram, including interconnections, of the main parts of a computer, and illustrate methods used on a computer for storing and retrieving data. (*Architecture and organization*)

Subdomains

ITE-PFT-01	Perspectives and impact [L1]	ITE-PFT-04	Architecture and organization [L1]
ITE-PFT-02	Operating systems [L3]	ITE-PFT-05	Application execution environment [L1]
ITE-PFT-03	Computing infrastructures [L1]		

ITE-SPA Domain: System Paradigms

Scope

1. Skills and tools to gather requirements, source code development, evaluation and integration of components into a single system, and system validation
2. Design, selection, application, deployment, and management of computing systems to support an organization
3. 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
4. Fundamentals of project management and the interplay between IT applications and related organizational processes
5. System integration issues, including integration in a system of systems and federation of systems, role of architectures in systems integration, performance and effectiveness
6. Education and support of users of computing systems

Competencies

A. Justify the way IT systems within an organization can represent stakeholders using different architectures and the ways these architectures relate to a system lifecycle. (*Requirements and development*)
B. Demonstrate a procurement process for software and hardware acquisition and explain the procedures one might use for testing the critical issues that could affect IT system performance. (*Testing and performance*)
C. Evaluate integration choices for middleware platforms and demonstrate how these choices affect testing and evaluation within the development of an IT system. (*Integration and evaluation*)
D. Use knowledge of information technology and sensitivity to the goals and constraints of the organization to develop and monitor effective and appropriate system administration policies within a government environment. (*System governance*)
E. Develop and implement procedures and employ technologies to achieve administrative policies within a corporate environment. (*Operational activities*)
F. Organize personnel and information technology resources into appropriate administrative domains in a technical center. (*Operational domains)*
G. Use appropriate and emerging technologies to improve performance of systems and discover the cause of performance problems in a system. (*Performance analysis*)

Subdomains

ITE-SPA-01	Perspectives and impact [L1]	ITE-SPA-06	Integration and deployment [L2]
ITE-SPA-02	Requirements [L2]	ITE-SPA-07	System governance [L2]
ITE-SPA-03	System architecture [L1]	ITE-SPA-08	Operational activities [L3]
ITE-SPA-04	Acquisition and sourcing [L2]	ITE-SPA-09	Operational domains [L3]
ITE-SPA-05	Testing and quality assurance [L2]	ITE-SPA-10	Performance analysis [L1]

ITE-SWF Domain: Software Fundamentals

Scope

1. Skills and fundamental programming concepts, data structures, and algorithmic processes
2. Programming strategies and practices for efficient problem solving
3. Programming paradigms to solve a variety of programming problems

Competencies

A. Use multiple levels of abstraction and select appropriate data structures to create a new program that is socially relevant and requires teamwork. (*Program development*)
B. Evaluate how to write a program in terms of program style, intended behavior on specific inputs, correctness of program components, and descriptions of program functionality. (*App development practices*)
C. Develop algorithms to solve a computational problem and explain how programs implement algorithms in terms of instruction processing, program execution, and running processes. (*Algorithm development*)
D. Collaborate in the creation of an interesting and relevant app (mobile or web) based on user experience design, functionality, and security analysis and build the app's program using standard libraries, unit testing tools, and collaborative version control. (*App development practices*)

Subdomains

ITE-SWF-01	Perspectives and impact [L1]	ITE-SWF-05	Fundamental data structures [L2]
ITE-SWF-02	Concepts and techniques [L2]	ITE-SWF-06	Algorithm principles and development [L2]
ITE-SWF-03	Problem-solving strategies [L1]	ITE-SWF-07	Modern app programming practices [L1]
ITE-SWF-04	Program development [L3]		

ITE-UXD Domain: User Experience Design

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. Application of evaluation criteria, benchmarks, and standards
5. User and task analysis, human factors, ergonomics, accessibility standards, experience design, and cognitive psychology

Competencies

A. Design an interactive application, applying a user centered design cycle and related tools and techniques (e.g., prototyping), aiming at usability and relevant user experience within a corporate environment. (*Design tools and techniques*)

B. For a case of user centered design, analyze and evaluate the context of use, stakeholder needs, state-of-the-art interaction opportunities, and envisioned solutions, considering user attitude and applying relevant tools and techniques (e.g., heuristic evaluation), aiming at universal access and inclusiveness, and showing a responsive design attitude, considering assistive technologies and culture sensitive design. (*Stakeholder needs*)

C. For evaluation of user centered design, articulate evaluation criteria and compliance to relevant standards (*Benchmarks and standards*)

D. In design and analysis, apply knowledge from related disciplines including human information processing, anthropology and ethnography, and ergonomics/human factors. (*Integrative design*)

E. Apply experience design for a service domain relate to several disciplines, focusing on multiple stakeholders and collaborating in an interdisciplinary design team. (*Application design)*

Subdomains

ITE-UXD-01	Perspectives and impact [L1]	ITE-UXD-05	Affective user experiences [L1]
ITE-UXD-02	Human factors in design [L2]	ITE-UXD-06	Human-centered evaluation [L1]
ITE-UXD-03	Effective interfaces [L2]	ITE-UXD-07	Assistive technologies and accessibility [L1]
ITE-UXD-04	Application domain aspects [L1]	ITE-UXD-08	User advocacy [L1]

ITE-WMS Domain: Web and Mobile Systems

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, social media

Competencies

A. Design a responsive web application utilizing a web framework and presentation technologies in support of a diverse online community. (*Web application development*)

B. Develop a mobile app that is usable, efficient, and secure on more than one device. (*Mobile app development*)

C. Analyze a web or mobile system and correct security vulnerabilities. (*Web and mobile security*)

D. Implement storage, transfer, and retrieval of digital media in a web application with appropriate file, database, or streaming formats. (*Digital media storage and transfer*)

E. Describe the major components of a web system and how they function together, including the web server, database, analytics, and front end. (*Web system infrastructure*)

Subdomains

ITE-WMS-01	Perspectives and impact [L1]	ITE-WMS-05	Development Frameworks [L2]
ITE-WMS-02	Technologies [L2]	ITE-WMS-06	Vulnerabilities [L1]
ITE-WMS-03	Digital media [L2]	ITE-WMS-07	Social software [L1]
ITE-WMS-04	Applications concepts [L2]		

6.3.2 Supplemental IT Domain Clusters

The following descriptions reflect the content of each supplemental IT domain cluster.

ITS-ANE Domain: Applied Networks	
Scope	**Competencies**
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	A. Design, develop and test a socket program that communicates between two different services using both TCP/IP sockets and datagram sockets, as well as a program that uses a messaging service to send asynchronous messages to another application across the network. (*Development and testing*) B. Contrast existing technologies to optimize and enhance mobile communications for a client-server architecture. (*Technologies*) C. Perform simulations and describe security and performance issues related to wireless networks. (*Security and performance*)
Subdomains	
ITS-ANE-01 Proprietary networks [L2] ITS-ANE-02 Network programming [L2] ITS-ANE-03 Routing protocols [L2] ITS-ANE-04 Mobile networks [L2]	ITS-ANE-05 Wireless networks [L2] ITS-ANE-06 Storage area networks [L1] ITS-ANE-07 Applications for networks [L2]

ITS-CCO Domain: Cloud Computing	
Scope	**Competencies**
1. Cloud 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. Emerging technologies and existing cloud-based infrastructure	A. Analyze the meaning of cloud computing and understand the different cloud service categories. *(Technologies)* B. Categorize cloud service types and be aware of privacy regulation impact on cloud application requirements. *(Legal and Design)* C. Consider contract negotiations needed for cloud service delivery and develop the skills necessary to assess security breaches and their impact on the organization. *(Risk Management)* D. Analyze when to use cloud applications and how architecture affects performance. *(Technology)* E. Develop a cloud application with a user interface and understand data components. *(Design)*
Subdomains	
ITS-CCO-01 Perspectives and impact [L1] ITS-CCO-02 Concepts and fundamentals [L2] ITS-CCO-03 Security and data considerations [L2] ITS-CCO-04 Using cloud computing applications [L2]	ITS-CCO-05 Architecture [L2] ITS-CCO-06 Development in the cloud [L2] ITS-CCO-07 Cloud infrastructure and data [L2]

ITS-CEC Domain: Cybersecurity Emerging Challenges

Scope

1. The emerging challenges in a computing-based discipline involving technology, people, information, and processes to enable assured operations and to support the growing need for forensic activities in a contest, adversarial environment.
2. Security considerations of cloud computing
3. Digital forensics including the recovery and investigation of material found in digital devices, often in relation to computer crime.
4. Security implications for information technologies enabled and controlled by software and influenced by the supply chain.

Competencies

A. Perform malware analysis on a computer system and conduct a forensic analysis on a local network, on stored data within a system as well as mobile devices for an enterprise environment. (*Malware and forensic analysis*)

B. Apply standards, procedures, and applications used to protect the confidentiality, integrity and availability of information and information system within a cloud computing setting. (*System integrity*)

C. Analyze human facets that enable the exploitation of computing-based systems. (*Human dynamics*)

D. Design security procedures, based on cybersecurity principles, regarding privacy issues for a computing-based system that address security challenges within a computing environment (e.g. internet of things). (*Security procedures*)

Subdomains

ITS-CEC-01	Case studies and lessons learned [L1]	ITS-CEC-07	Malware analysis [L1]
ITS-CEC-02	Network forensics [L2]	ITS-CEC-08	Supply chain and software assurance [L1]
ITS-CEC-03	Stored data forensics [L2]	ITS-CEC-09	Personnel and human security [L1]
ITS-CEC-04	Mobile forensics [L1]	ITS-CEC-10	Social dimensions [L1]
ITS-CEC-05	Cloud security [L1]	ITS-CEC-11	Security implementations [L1]
ITS-CEC-06	Security metrics [L1]	ITS-CEC-12	Cyber-physical systems and the IoT [L1]

ITS-DSA Domain: Data Scalability and Analytics

Scope

1. Key technologies used in collecting, cleaning, manipulating, storing, analyzing visualizing, and extracting useful information from large and diverse data sets.
2. Data mining and machine learning algorithms for analyzing large sets of structured and unstructured data.
3. The challenges of large scale data analytics in different application domains.

Competencies

A. Use appropriate data analysis methods to solve real-world problems. (*Requirements and development*)

B. Perform data preprocessing techniques - data integration, data cleansing, data transformation and data reduction to clean and prepare data sets for analysis. (*Testing and performance*)

C. Use big data platforms including but not limited to Hadoop, Spark, and tools including but not limited to R and RStudio, MapReduce and SAS to analyze data in different application domains. (*Testing and performance*)

D. Use data-intensive computations and streaming analytics on cluster and cloud infrastructures to drive better organization decisions. (*Testing and performance*)

E. Examine the impact of large-scale data analytics on organization performance using case studies. (*Integration and evaluation*)

Subdomains

ITS-DSA-01	Perspectives and impact [L1]	ITS-DSA-04	Methods, techniques, and tools [L2]
ITS-DSA-02	Large-scale data challenges [L2]	ITS-DSA-05	Data governance [L2]
ITS-DSA-03	Data management [L2]	ITS-DSA-06	Applications [L2]

ITS-IOT Domain: Internet of Things

Scope	Competencies
1. Basic knowledge and skills to engage in innovative design and development of IoT solutions 2. Trends and characteristics in the IoT field 3. Analysis of challenges and application patterns for user-interaction in IoT settings 4. IoT effects for signal processing, data acquisition, and wireless sensor networks 5. Relationships between IoT and intelligent information processing 6. Internet operations compared with internet of things operations	A. Design various domains, key components, and architectural frameworks and then interface sensors and actuators for signal processing within an IoT burglar alarm system. (*IoT system design and development*) B. Use wireless sensors within an ad-hoc networks architecture to capture data within a multimedia system. (*Wireless data acquisition*) C. Evaluate the successful relevance applications for an IoT system using intelligent information processing and automatic control systems. (*IoT system evaluation*)

Subdomains

ITS-IOT-01	Perspectives and impact [L1]	ITS-IOT-06	Ad-hoc networks [L1]
ITS-IOT-02	IoT architectures [L2]	ITS-IOT-07	Automatic control [L2]
ITS-IOT-03	Sensor and actuator interfacing [L1]	ITS-IOT-08	Intelligent information processing [L2]
ITS-IOT-04	Data acquisition [L1]	ITS-IOT-09	IoT application and design [L2]
ITS-IOT-05	Wireless sensor networks [L2]		

ITS-MAP Domain: Mobile Applications

Scope	Competencies
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	A. Contrast the global scope of architectures within different mobile systems. (Requirements and Technologies) B. Compare several hybrid web applications through an application programming interface (API) and a platform-independent interpreted web application. (*Technologies*) C. Design a server side application using several techniques for server-side programming. (*Design and Development*) D. Analyze and contrast the implementation of cross-platform 2D graphics and animation using an object-oriented language. (*Technologies and Implementation*)

Subdomains

ITS-MAP-01	Perspectives and impact [L1]	ITS-MAP-06	Views and gestures [L1]
ITS-MAP-02	Architectures [L1]	ITS-MAP-07	Interface implementations [L2]
ITS-MAP-03	Multiplatform mobile application development [L2]	ITS-MAP-08	Camera, state, and documents interaction [L1]
ITS-MAP-04	Servers and notifications [L1]	ITS-MAP-09	2D graphic and animation [L1]
ITS-MAP-05	Performance issues [L1]		

ITS-SDM Domain: Software Development and Management	
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	**Competencies** A. Use tools and services to develop computing systems that take into account platform constraints, supports version control, tracks requirements and bugs, and automates building. (*Development*) B. Use project management tools and metrics to plan, monitor, track progress, and handle risks that affect decisions in a computing systems development process involving a diverse team of talents and professional experiences. (*Management*)
Subdomains	
ITS-SDM-01 Process models and activities [L2] ITS-SDM-02 Platform-based development [L1] ITS-SDM-03 Tools and services [L2]	ITS-SDM-04 Management [L2] ITS-SDM-05 Deployment, operations, maintenance [L2]

ITS-SRE Domain: Social Responsibility	
Scope 1. Social, governmental regulations and environmental context of IT and computing 2. Importance of Team Dynamics, Ethics and Professionalism to an organizations success 3. Information Technology and the role of Risk Management 4. Energy Management and Standards leading to "Green Computing"	**Competencies** A. Analyze the role that teamwork, ethics and legal considerations play within a governmental IT setting. (*Teamwork, legal and ethical considerations*) B. Evaluate governmental and environmental regulations and how they affect an organization's environment. (*Government and environment*) C. Develop the skills necessary to evaluate and assess security breaches and their effect on business within a banking environment. (*Risk management*) D. Analyze and develop use and delivery projects using current energy standards. (*Energy considerations*)
Subdomains	
ITS-SRE-01 Social context of computing [L2] ITS-SRE-02 Goals, plans, tasks, deadlines, and risks [L2] ITS-SRE-03 Government role and regulations [L1]	ITS-SRE-04 Global challenges and approaches [L1] ITS-SRE-05 Risk management [L1] ITS-SRE-06 Sustainable Computing [L1]

ITS-VSS Domain: Virtual Systems and Services	
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	**Competencies** A. Contrast virtualized and non-virtualized platforms. *(Technologies)* B. Implement virtualization for applications, desktops, servers and network platforms. *(Install technologies)* C. Install and configure a storage environment and use performance measurement tools. (*Technologies and performance*)
Subdomains	
ITS-VSS-01 Perspectives and impact [L1] ITS-VSS-02 Application of virtualization [L2] ITS-VSS-03 User platform virtualization [L1] ITS-VSS-04 Server virtualization [L1]	ITS-VSS-05 Network virtualization [L2] ITS-VSS-06 Cluster design and administration [L2] ITS-VSS-07 Software cluster applications [L2] ITS-VSS-08 Storage [L1]

6.4 Contemporary Illustration of IT

This section presents a modern image of IT curricula. Before presenting an image to represent information technology, consider first Table 6.5, which is a version of Table 6.1. Table 6.5 shows the nineteen IT domains (ten essential domains plus nine supplemental domains) as presented in this report together with nineteen *distinct* colors associated with each domain. Table 6.5 organizes the domains in three groupings: essential only (5), supplemental only (4), and essential + supplemental (5 + 5). The grouping that contain both essential and supplemental classifications, shows similar colors but with different degrees of intensity.

Table 6.5: IT Curricular framework and relative colors

IT Domains	Essential Domains	Supplemental Domains
Essential Only (5)		
Information Management (ITE-IMA)		
Integrated Systems Technology (ITE-IST)		
Platform Technologies (ITE-PFT)		
System Paradigms (ITE-SPA)		
User Experience Design (ITE-UXD)		
Essential + Supplemental (5 + 5)		
Cybersecurity Principles (ITE-CSP) / Cybersecurity Emerging Challenges (ITS-CEC)		
Global Professional Practice (ITE-GPP) / Social Responsibility (ITS-SRE)		
Networking (ITE-NET) / Applied Networks (ITS-ANE)		
Software Fundamentals (ITE-SWF) / Software Development and Management (ITS-SDM)		
Web and Mobile Systems (ITE-WMS) / Mobile Applications (ITS-MAP)		
Supplemental Only (4)		
Cloud Computing (ITS-CCO)		
Data Scalability and Analytics (ITS-DSA)		
Internet of Things (ITS-IOT)		
Virtual Systems and Services (ITS-VSS)		

Recall that the essential domains form the core of an IT curriculum. The supplemental domains provide texture with enhancements and embellishments to reflect the local needs of a program's mission and constituents. That is, a modern image should depict the essential and the supplemental meanings of a curriculum carefully woven together into a tapestry of relevance and utility for the IT field.

Figure 6.3 illustrates a tapestry as a modern version of information technology. For this illustration, the weft threads (vertical) of the tapestry go through the warp threads (horizontal). In this case, the ten warps represent the ten essential domains of the IT curricular framework; the nine wefts represent the nine supplemental domains of the framework. Note that one warp thread (ITE-CSP) permeates both warp and weft roles in the image, which emphasizes that cybersecurity is a contemporary 'thread' woven throughout the tapestry – and hence, the field of information technology. This woven warp thread may change name over time as IT evolves. The resulting image provides a pictorial illustration showing the way IT weaves the breadth of computing.

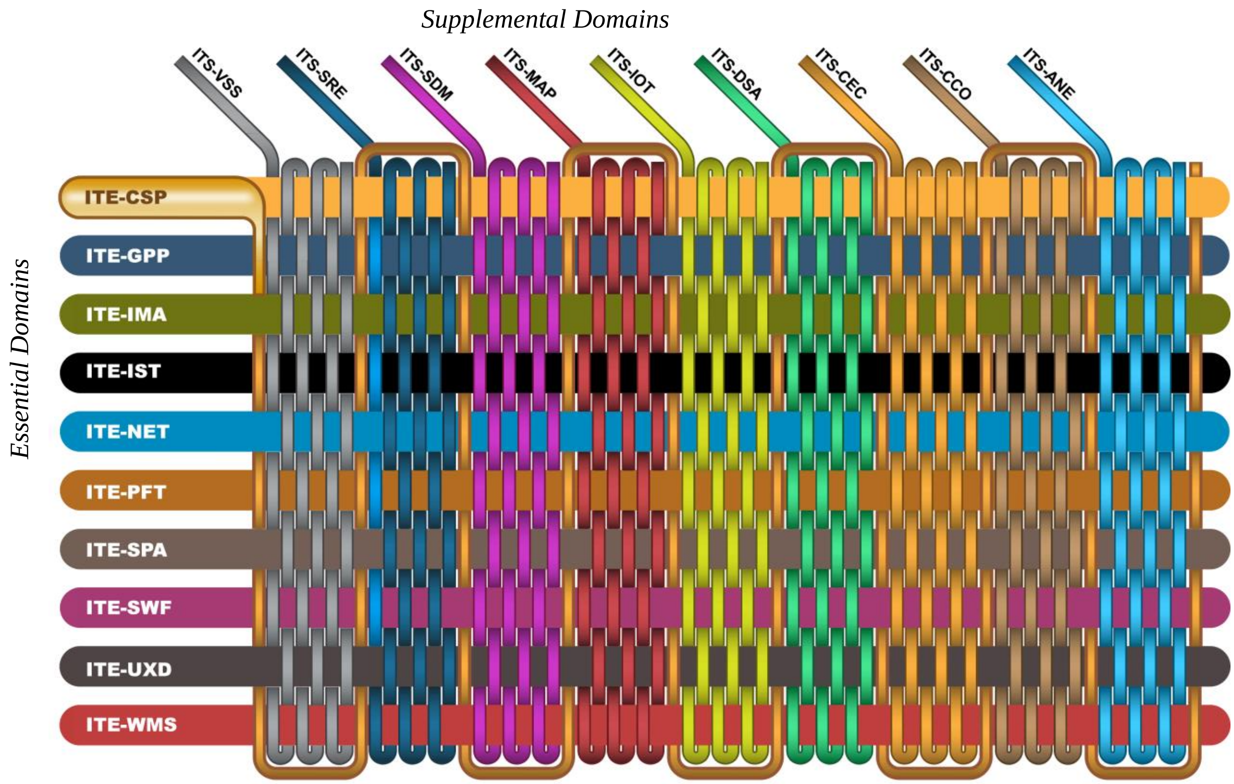

Figure 6.3: Modern illustration depicting the field of IT (Courtesy of Richard Fry)

New technologies keep emerging thereby amplifying the integration of IT competencies. Figure 6.3 attempts to capture the spirit of future IT innovations by allowing the warp threads and the weft threads to weave the tapestry of a dynamic and relentlessly evolving IT field.

Chapter 7: 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 7.1 addresses general requirements that support the broad education of IT students, including the non-technical skills described in Chapter 5 that are so important to success in the industry. Section 7.2 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 7.3 shows how should IT professionals relate to an era of emerging technologies.

7.1 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 to apply computing 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.

7.1.1 Communication Skills

As stated in Chapter 5, 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. Particularly, 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 in isolation; instead, they should be a recurring theme within the IT curriculum and its requirements.

7.1.2 Teamwork Skills

As mentioned in Chapter 5, computing professionals cannot expect to work in isolation for very much of the time. Usually, a diverse group of people working together as a team implement information technology projects. 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 can 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.
- Significant projects that involves a complex implementation task in which a small student team undertakes both its design and implementation.
- Major projects scheduled during the last year of undergraduate study, where it can serve as a capstone for the undergraduate experience.

Teachers can enhance the experience students derive from a significant team project 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.

7.1.3 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.

7.1.4 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 could be extremely useful and doable 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, teachers should encourage IT students to consider a concentration in another discipline. Such opportunities exist in such fields as health, economics, statistics, data science, business, the sciences, and many other disciplines.

7.1.5 Becoming a Contributing Member of Society

Regardless of the depth or focus of one's technical background, each person should perform 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.

7.2 IT Curricular Framework and IT Programs

7.2.1 Tailoring the Curriculum

The IT curricular framework presented in this report consists of essential and supplemental IT domains, as discussed in Chapter 6. An IT program curriculum should 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, 20% of the IT component can come from the supplemental IT domains to construct a curriculum that meets the needs of a local 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 20% could produce a graduate with too much breadth and not enough depth to have useful skills in today's job market.

7.2.2 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 reach a 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 several the universities in Scotland have opted out of this system. Such accreditation is 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 are starting to reflect 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 becomes 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 baccalaureate degree programs in computer science, information system science, and in general, in information and communication technologies (ICT) can come from universities and from polytechnics (universities of applied sciences). For new students, most of the universities’ master’s programs begin with baccalaureate 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, geo-informatics, big data, and human-technology interaction). People's interest towards IT in general and ICT education 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 occur 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 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 countries mentioned above. 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.

7.3 IT Curricular Models

The following discussion addresses several curricular models or examples reflecting a curriculum in information technology. They consist of traditional four-year illustrations followed by other illustrations that include interdisciplinary, three-year, and 2+2 models.

7.3.1 Traditional Four-year IT Programs

As with other curricular reports, the focus is on a four-year curriculum assuming entering students have the proper qualifications for admission. In some instances, students may have to take up to a year of preparatory work in areas such as mathematics, English, or other experiences to bolster their chances for success in completing an information technology program. The credits earned during this developmental or foundational year, sometimes known as "Year 0" at some institutions, do not count toward the attainment of the degree. Appendix C illustrates curricular models or examples for students entering a traditional four-year program in information technology without reference to any remedial or foundational studies.

7.3.2 IT Programs in Different Contexts

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 discipline. 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.

When considering how to integrate the information technology curriculum into degree programs we should consider the curricular time available. From Chapter 6 of this report, we see that most degree programs offer about 2.5 years of instruction outside of general education requirements. The proposed information technology curriculum recommendation takes 1.5 years to complete. This leaves 1.5 years for free technical electives or other curricular requirements. The key to fitting the information technology curriculum into the larger program lies in what to do with the free technical electives and "other" curricular space.

7.3.2.1 Information Technology as a Major in a Larger Degree

A common version of this is an information technology major in a bachelor of science degree. The available curricular space must be used to meet the general requirements of the degree program. Any remaining time can be allocated to free technical electives.

We also note that frequently in this context the information technology discipline "grew" out of an existing computer science major. As a result, many information technology programs have other names and information technology experiences may have a classification as 'computer science' or 'computer information systems' courses.

7.3.2.2 Information Technology Degree with a Concentration in Another Discipline

A common implementation of this is a medical information technology program. In this situation, the unassigned curricular space might go to the other discipline. There may still not be enough space in which case it will be necessary to reduce the amount of curricular space devoted to information technology. To do this, remove one or more of the supplemental domains in the model. Try to remove the domains least relevant to the other discipline. We recommend that the program removes one whole domain rather than taking parts out of several domains. This is because the competencies listed for a domain interlink. In some cases, elimination of one essential domain that is less relevant to the degree might receive acceptance such as networking in healthcare informatics.

7.3.2.3 Information Technology is a Concentration in a Larger Degree Program

In this situation, the 'other' discipline might dictate most of the degree requirements. Probably only the equivalent of one academic year would be available to information technology. Conveniently, the essential part of the information technology curricular recommendations only requires one year for completion. Note also that professional practice courses in the larger discipline may cover the significant parts of the 'global professional practice' essential domain.

7.3.2.4 Related Issues

Information technology is a divers field of study and its content varies by country and by region. To show this diversity, Appendix D illustrates examples of information technology programs offered within different contexts, which shows the breadth of information technology in different locales. The task group is also aware of the overlap of IT with other curricular reports (e.g., cross-coding issues), initiatives to promote the study of computing in pre-university settings (e.g., the CS Principles initiative in the United States), as well as the need for diversity and inclusion. Discussion of these issues should take place in other settings beyond this report.

7.4 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.

7.4.1 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.

7.4.2 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 8: Institutional Adaptations

This chapter serves 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.

8.1 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 specific areas.
- *The specific needs of the local industry.* Individual curricula often customized to meet the needs of local organizations.

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.

8.2 Principles for Curriculum Design

Even though 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 recognized discipline. That discipline, moreover, reflects a combination of theory, practice, knowledge, and skills. Any information technology curriculum should, therefore, ensure that practice follows both 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 follow the outcomes the program intends 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 program achieves these goals 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 should maintain a consistent ethos that promotes innovation, creativity, and professionalism.* Students respond best when they understand expectations. It is unfair to students to encourage special modes of behavior in early courses, only to discourage that same behavior in later courses. Throughout the entire curriculum, teachers should encourage students to use their initiative and imagination to go beyond the minimal requirements. At the same time, from the very beginning, students should 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 ethnic, 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. IT programs should provide reasonable accommodations for students with qualifying disabilities under local or regional government regulatory laws such as the Americans with Disabilities Act (ADA) or Section 504 of the Rehabilitation Act. When selecting tools, software or learning materials, departments should consider accessibility requirements for students of all abilities.

- *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 may not conform adequately in a formal classroom setting. Students may only be able to learn these skills in a 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.

8.3 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 [Sab7], 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 [Ame1]. 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-recognized 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 between the two are available on the ACM CCECC website. A mapping to IT2008 is also available [Acm4]. Appendix D contains a 2+2 scenario where students complete an associate degree (first and second years) at a community college and then transfer to a four-year institution for their third and fourth years.

Outside the United States transfer from two-year to four-year institutions is less common. In Japan, for example, graduates of junior technical colleges can enroll in the third year of four-year institution through a selection process. However, the number of such students is less than 10% of the entire student population. In general, the proportion of non-traditional students is much higher in graduate schools compared to undergraduate institutes in Japan.

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

The situation varies in Europe. 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 became four years; one- or two-year master's degrees were available for specialization. Currently, the curriculum 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 institutions into universities.

8.4 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].

8.5 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 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].

8.6 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 members 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.

8.7 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 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 concentration 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 concentration 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.

8.8 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 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: Enterprise IT Skill Frameworks

(From the IEEE Computer Society EITBOK project)

A.1 Competency Frameworks

The emphasis on competence has become international as Enterprise IT and ICT in general have become indispensable across the globe. They derive from a growing understanding of the need for a common language for competences, knowledge, skills and proficiency levels that can be understood across national borders. A common framework enables the identification of skills and competences that may be required to successfully perform duties and fulfill responsibilities in an EIT workplace. They provide a common basis for the selection and recruitment of EIT staff, as well as forming the basis for employment agreements, professional development plans, and performance evaluation for ICT professionals.

Many national and regional governments have come to require certification of EIT practitioners. Accordingly, they have had to develop their own definitions of ICT competences. Given the increasingly international composition of the EIT workforce, the EITBOK has included information from 3 major frameworks that are emerging as inter-regional. In general, these frameworks work towards a common understanding of competence, defined by the e-CF, for example, as “demonstrated ability to apply knowledge, skills and attitudes to achieve observable results."

Creating mappings between these frameworks and our chapters is challenging, because they come from different perspectives and have different goals. There is rarely a 100% correspondence between the frameworks and our chapters, and, despite careful consideration some subjectivity was used to create the mappings. Please take that in consideration as you review them.

A.2 Skills Framework for the Information Age

SFIA has been used for some 26 years and developed using a collaborative approach. The internationally represented SFIA Council oversees the direction of development for the not-for-profit SFIA Foundation, which owns and regularly updates the framework, using a well-established open process, for the benefit of the IT industry and IT professionals. The SFIA Framework has been translated in to 6 languages (English, Spanish, German, Arabic, Japanese and Chinese with more languages scheduled including French and French Canadian). It has been downloaded and used by organizations and individuals in nearly 180 countries. It can be downloaded for free at www.sfia-online.org.

The SFIA Framework identifies 97 professional skills across IT and supporting areas and 7 levels of responsibility. The 7 levels in the SFIA Framework are used to provide generic levels of responsibility and to reflect experience and competency. The SFIA Framework is based on demonstrated ability of applying a skill at a particular level, employing professional and behavioural skills as well as knowledge. The definitions describe the behaviors, values, knowledge and characteristics that an individual should have in order to be considered competent at a particular level. Underlying each SFIA Level are generic responsibilities of Autonomy, Complexity, Influence and Business Skills. These are described at each SFIA Level.

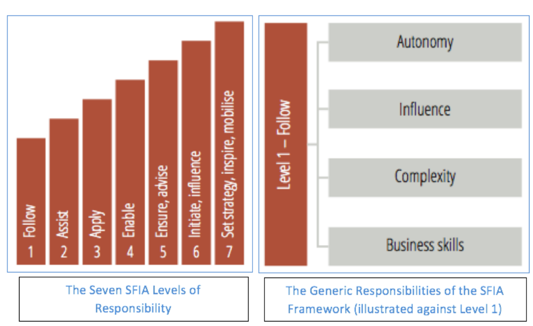

Figure A.1: SFIA Levels of Responsibility

The 97 IT skills of the SFIA Framework are grouped into categories and sub-categories, a skill has a name, a code, a skill description and a level description (for that skill at each level practiced).

Attribute	Description
General Responsibilities	The generic responsibility attributes delineated for all skills at all SFIA Levels: • Autonomy • Complexity • Influence • Business Skills
Skill Category	A logical grouping of the skills for the purposes of navigation.  These categories are further broken down into sub-categories.
Skill Name	The name of the skill
Skill Description	A description of what the skill is without reference to the levels practiced
Level Descriptors	A description of the skill for each of the levels practiced, phrased to facilitate their use as professional competencies. • Level 1 — Completes work tasks under close supervision. Seeks guidance in unexpected situations. Has an organized approach to work? Works with immediate colleagues only. • Level 2 — Uses some discretion to resolve issues or deal with enquiries. Works on a range of tasks, and proactively manages personal development. • Level 3 — Works under general direction only but has worked reviewed at regular intervals. Knows when to escalate problems / questions to a higher level. Works with suppliers and customers. May have some supervisory responsibility for less experienced staff. Performs a broad range of tasks, some complex. Plans schedules and monitors own work. • Level 4 — Has substantial personal responsibility and autonomy. Plans own work to meet objectives and execute end to end processes. Makes decisions which influence the success of projects and team objectives. Executes a broad range of complex technical or professional activities. • Level 5 — Broad direction, objective setting responsibility. Influences organization. Build effective working relationships. Performs Challenging and unpredictable work. Self-sufficient in business skills. Advises others on standards methods and tools. • Level 6 — Has authority for a significant area of work. Sets organizational objectives. Influences policy, customers and suppliers at a senior level. Performs Highly complex and strategic work. Initiates and leads technical and organizational change. • Level 7 — At the highest organizational level, has authority over all aspects of a significant area of work, including policy formation and application. Makes decisions critical to organizational success. Inspires the organization, and influences developments within the industry at the highest levels. Develops long-term strategic relationships.

A.3 European Competency Framework

The European e-Competence Framework (e-CF) from the European Union provides a reference of 40 competences required for performance in the Information and Communication Technology (ICT) workplace, using a common language for competences, knowledge, skills and proficiency levels that can be understood across Europe. The use of the e-CF by companies and organizations throughout Europe supports the transparency, mobility and efficiency of ICT sector related human resources planning and development.

As the first sector-specific implementation of the European Qualifications Framework (EQF), the e-CF can be used by ICT service, demand and supply organizations, and by managers and HR departments, for education institutions and training bodies, including higher education, by professional associations, trade unions, market analysts and policy makers, and other organizations and parties in public and private sectors. The structure of the framework is based on four dimensions:

Dimension 1	5 e-Competence areas, derived from the ICT business macro-processes PLAN – BUILD – RUN – ENABLE – MANAGE. Main aim of dimension 1 is to facilitate navigation through the framework
Dimension 2	A set of reference e-Competences for each area, with a generic description for each competence. 40 competences identified in total provide the European generic reference definitions of the framework.
Dimension 3	Proficiency levels of each e-Competence provide European reference level specifications on e-Competence levels e-1 to e-5, which are related to EQF levels 3-8.
Dimension 4	Samples of knowledge and skills relate to e-Competences in dimension 2. They are provided to add value and context and are not intended to be exhaustive.

There are five e-CF proficiency levels, e-1 to e-5, which relate to EQF learning levels 3 to 8. For a description of the EQF levels, please see https://ec.europa.eu/ploteus/en/content/descriptors-page.

e-Competence Level	**EQF Level**
5 (highest)	8
4	7
3	6
2	4 and 5
1	3

As in SFIA, not all skills are subject to all 5 levels. The following table shows the spread of competency levels for each skill.

Dimension 1 5 e-CF areas (A – E)	Dimension 2 40 e-Competences identified	Dimension 3 e-Competence proficiency levels e-1 to e-5, related to EQF levels 3–8				
		e-1	e-2	e-3	e-4	e-5
A. PLAN	A.1. IS and Business Strategy Alignment				■	■
	A.2. Service Level Management			■	■	
	A.3. Business Plan Development			■	■	■
	A.4. Product/Service Planning		■	■	■	
	A.5. Architecture Design			■	■	■
	A.6. Application Design	■	■	■		
	A.7. Technology Trend Monitoring				■	■
	A.8. Sustainable Development			■	■	
	A.9. Innovating				■	■
B. BUILD	B.1. Application Development	■	■	■		
	B.2. Component Integration		■	■	■	
	B.3. Testing	■	■	■	■	
	B.4. Solution Deployment	■	■	■		
	B.5. Documentation Production	■	■	■		
	B.6. Systems Engineering			■	■	
C. RUN	C.1. User Support	■	■	■		
	C.2. Change Support		■	■		
	C.3. Service Delivery	■	■	■		
	C.4. Problem Management		■	■	■	
D. ENABLE	D.1. Information Security Strategy Development				■	■
	D.2. ICT Quality Strategy Development				■	■
	D.3. Education and Training Provision		■	■		
	D.4. Purchasing		■	■	■	
	D.5. Sales Proposal Development		■	■		
	D.6. Channel Management			■	■	
	D.7. Sales Management			■	■	■
	D.8. Contract Management		■	■	■	
	D.9. Personnel Development		■	■	■	
	D.10. Information and Knowledge Management			■	■	■
	D.11. Needs Identification			■	■	■
	D.12. Digital Marketing		■	■	■	
E. MANAGE	E.1. Forecast Development			■	■	
	E.2. Project and Portfolio Management		■	■	■	■
	E.3. Risk Management		■	■	■	
	E.4. Relationship Management			■	■	
	E.5. Process Improvement			■	■	
	E.6. ICT Quality Management		■	■	■	
	E.7. Business Change Management			■	■	■
	E.8. Information Security Management		■	■	■	
	E.9. IS Governance				■	■

Figure A.2: The European Competency Framework Overview

A.4 The i Competency Dictionary

The i Competency Dictionary (iCD) was developed and is maintained by the Information Technology Promotion Agency (IPA) in Japan. It consists of a comprehensive Task Dictionary and a corresponding Skill Dictionary. The Task Dictionary contains all the tasks that EIT outsourcers or EIT departments are expected to accomplish, while the corresponding Skill Dictionary provides the skills required to perform those tasks.

The diagrams below show how the task and skill dictionaries are structured to be used together. The skills needed to become competent at each task are enumerated in a Task vs. Skill table. In each of the EITBOK chapters, we have shown one of the relevant tasks (at Task layer 2), along with its prerequisite skills from layers 2-4. In the diagrams below, we have indicated the number of tasks and skills that are included in the full iCD. The complete iCD Task Dictionary (Layers 1-4) and Skill Dictionary (Layers 1-4) can be obtained by returning the request form provided from: http://www.ipa.go.jp/english/humandev/icd.html

Note that the IPA is also responsible for the Information Technology Engineers Examination (ITEE), which has grown into one of the largest scale national examinations in Japan, with approximately 600,000 applicants each year.

A.4.1 Task Dictionary

The Task Dictionary is intended to be used and applied by companies and organizations to determine tasks in line with their organizational strategies or organization plans. Tasks are used to define their organizational functions and the roles of personnel. The structure of the dictionary assumes a wide range of corporate activities, so that companies with any kind of business model can use and apply it. The Task Dictionary is comprised of four layers that are divided into three task layers plus the Task Evaluation Items layer (approx. 2,000 items).

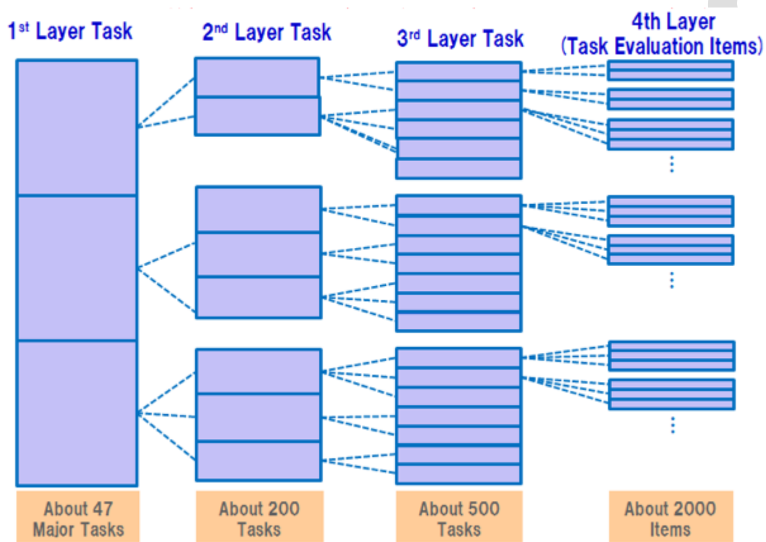

Figure A.3: The iCD Task Dictionary Structure

A.4.2 Task Dictionary Chart

The Task Dictionary Chart can be used to obtain a bird's-eye view of the entire Task Dictionary on the 1st Layer Task level. This chart represents a task structure composed of the organization lifecycle as vertical line (strategy, planning, development, utilization, evaluation/improvement) and tasks associated with entire lifecycle as horizontal line (Management/Control, and Promotion/Support).

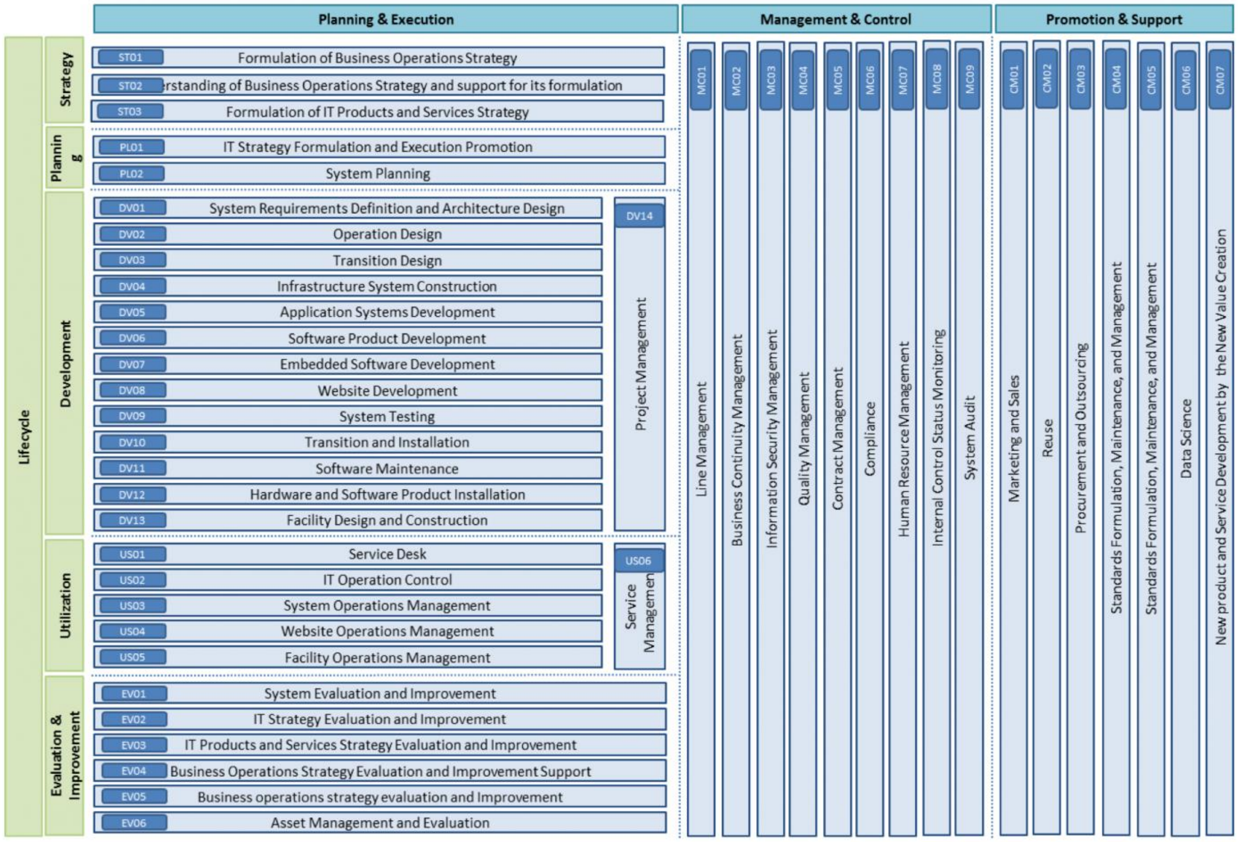

Figure A.4: The iCD Task Dictionary Chart

A.4.3 Examples of Task Evaluation Diagnostic Level and Criteria

This table is intended to define the task diagnostic level and Criteria. Diagnostic Criteria can be applied to task evaluation items or appropriate layer tasks to evaluate one's task performance capability. The levels are from L0 to L4. This Diagnostic Criteria can be applied to individuals and the total task performance capability is manipulated for each department by aggregating all department members result.

Diagnostic Level	Diagnostic Criteria
L0	No knowledge or experience
L1	Has knowledge based on training
L2	Can carry out with support or has such experience
L3	Can carry out independently or has such experience
L4	Can instruct others or has such experience

Figure A.5: Examples of Task Evaluation Diagnostic Level and Criteria

A.4.4 Skill Dictionary

Skills are capabilities required to handle associated knowledge items to execute a task. The Skill Dictionary is comprised of four layers divided into three skill layers plus Associated Knowledge Items (approx. 10,000 knowledge items). The Skill Dictionary refers and sorts the items from the major Body of Knowledges/processes and skill standards in the world.

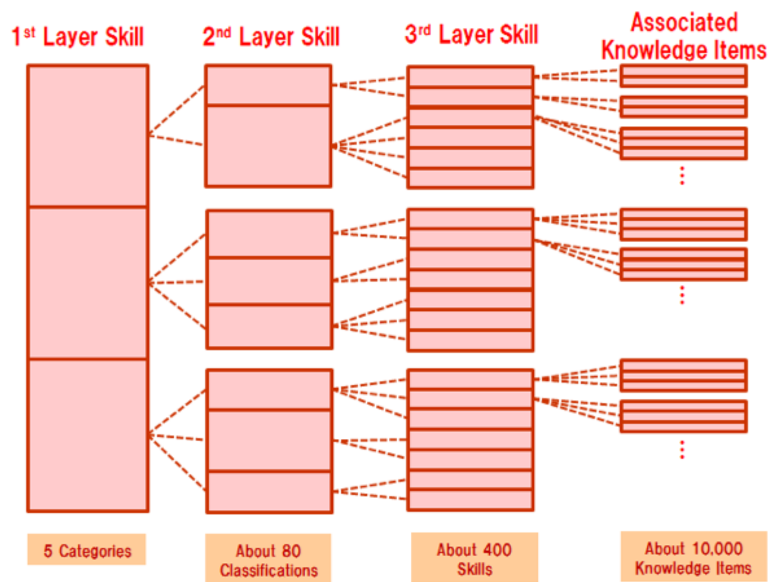

Figure A.6: The iCD Skill Dictionary Structure

A.4.5 Skill Dictionary Chart

The Skill Dictionary Chart can be used to obtain a bird's-eye view of the entire Skill Dictionary on the 1st and 2nd skill layers. The Skill Dictionary is divided into five categories based on the skill characteristics: methodology, technology, related knowledge, IT human skills, and specific skill (optional). This chart represents a skill structure on the perspectives of the IT orientation (Horizontal line: High-Low) and the application area (Vertical line: Wide-Narrow).

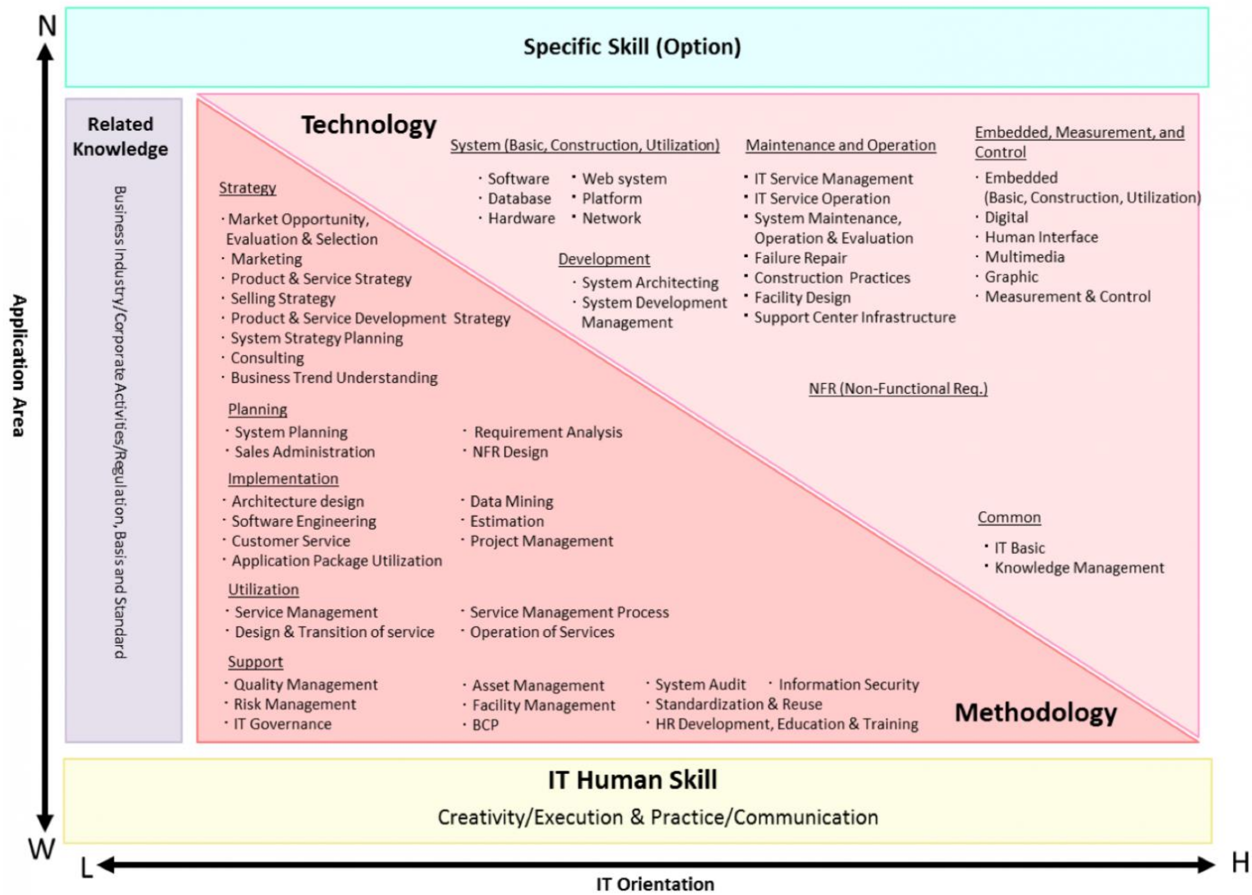

Figure A.7: The iCD Skill Dictionary Chart

A.4.6 Skill Proficiency Level

This chart measures the skill proficiency level using seven levels of skill proficiency criteria. Level 1 to 4 criteria differs according to contents of technology/methodology/related knowledge. Skill proficiency level 4 is the highest acquisition level of the skill for the task accomplishment. Level 5 to 7 criteria is defined across the categories to evaluate by social contribution degree as a professional.

Level 7	Skills at the level of an industry leader who has influence on the market		
Level 6	Skills at the level of a recognized contributor to the industry		
Level 5	Skills at the level of a recognized contributor within affiliated associations and organizations		
Level 4	Level at which one is able to produce optimal solutions that take into account non-functional requirements, step outside of established tactics, and pass the advanced information technology examinations	Has mastered and can select the most suitable methods, and can freely apply the methods according to the situation	Is able to discuss what needs to be done with senior management within the industry or business they are involved in
Level 3	Is able to create functional requirements and to work independently under limited circumstances	Is able to apply the proper method according to the problem, and has utilized the methods on-site and drawn conclusions	Has proposed solutions to the IT-related problem points in the industry and businesses they are involved in
Level 2	Has implementation experience, and is able to use and apply the technology if instructions are available	Is able to perform analysis using the method, or is able to use the methodology under guidance	Understands the IT-related problem points in the industry and businesses they are involved in
Level 1	Has knowledge, and understands lectures and presentations of technical content	Understands lectures and presentations about the method, understands and can explain what it is, and understands textbooks about it	Understands and can explain what kind of industry and business they are involved in, and understands public information such as securities reports
Category	Technology	Methodology	Related Knowledge

Figure A.8: Skill Proficiency Level

Appendix B: Performances

B.1 Essential IT Domains

ITE-CSP Cybersecurity Principles

ITE-CSP-01 Perspectives and impact

a. Make sense of the hard problem areas in cybersecurity that continue to make cybersecurity a challenge to implement.
b. Describe how a significant cybersecurity event has led to increased organizational focus on cybersecurity.
c. Tell a story of a significant cybersecurity advance.
d. Evaluate when the Confidentiality, Integrity and Availability (CIA) of information has been or could be violated with regards to providing trust of information.
e. Compare and evaluate different approaches/implementations of digital currencies.

ITE-CSP-02 Policy goals and mechanisms

a. Recognize when an organization focus is on compliance with standards vs. state of the practice vs. state of the art?
b. Be aware of multiple definitions for the word "policy" within a cybersecurity context.
c. Consider vulnerability notification and the issues associated with fixing or not fixing vulnerabilities and disclosing or not disclosing vulnerabilities.
d. Contrast the implications of relying on open design or the secrecy of design for security.
e. Express why cybersecurity is a societal imperative.

ITE-CSP-03 Security services, mechanisms and countermeasures

a. Analyze the tradeoffs of balancing key security properties (Confidentiality, Integrity, and Availability).
b. Make sense of the concepts of risk, threats, vulnerabilities and attack vectors (including the fact that there is no such thing as perfect security).
c. Document an example of "countermeasures" for specific threats.
d. Produce a list capabilities and tools that identify cybersecurity risks on an ongoing basis.
e. Show the concept of identity management and how it is important.
f. Make meaning of the concepts of authentication, authorization, and access control.
g. Argue the benefit of multi-factor authentication.

ITE-CSP-04 Cyber-attacks and detection

a. Contrast the roles of prevention, deterrence, and detection mechanisms.
b. Recognize password guessing, port scanning, SQL injection probes, and other cyberattacks in log files.
c. Make sense of the role and limitations of signature-based and behavioral-based anti-virus technology.
d. Contrast host-based and network-based intrusion detection systems.
e. Design several rules for a network-based intrusion detection system that will protect against specific known attacks.
f. Describe how the use of deception by malware is used to evade security mechanisms.

ITE-CSP-05 High assurance systems

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

ITE-CSP-06 Vulnerabilities, threats and risk

a. Express the difference between vulnerabilities, threats and risk.
b. Describe how security mechanisms can contain vulnerabilities.
c. Use a risk management framework.
d. Use penetration-testing tools to identify a vulnerability.
e. Derive several benefits of defense in depth, i.e. having multiple layers of defenses.
f. Describe how security issues arise at boundaries between components.
g. Use the National Vulnerability Database to determine if software installed on a server or network component has a known vulnerability.

h. Recognize vulnerabilities, threats and risks that are distinct to network infrastructure, cloud computing servers, desktop computers, and mobile devices.
i. Use a buffer-overflow attack against a server that reads an unbounded data into a fixed-size data structure.
j. Use 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

a. Compare the limitations and strengths of anonymous communication and payment systems currently in use.
b. Propose legitimate and illicit uses of anonymity systems.
c. Model policies for prohibiting or using anonymity systems within an organization.
d. Use an anonymity system (e.g. Tor).
e. Document the kind of 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

a. Describe how the concept of “psychological acceptability” and the importance of usability impact security mechanism design.
b. Make sense of research studies that consistently demonstrate that a trust-oriented interface design can facilitate the development of more trustworthy systems.
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. Recognize the differences between erasing pointers to information and overwriting the information as they apply to file systems, databases, and cloud storage.
g. Judge the effectiveness of an authentication mechanism from the perspective of a person who is visually impaired.
h. Design and develop software suite for a new digital currency.

ITE-CSP-09 Cryptography overview

a. Exhibit comprehension of 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. Contrast encryption, digital signatures, and hash functions.
c. Compare encryption for data at rest and data in motion.
d. Make sense of block-level encryption, file-level encryption, and application-level encryption for encrypted storage.
e. Argue why it is preferred to use validated, proven algorithms and implementations rather than developing new ones.

ITE-CSP-10 Malware fundamentals

a. Tell a story of how malware is concealed and the impact that malware might have on a system.
b. Use signature-based or behavior detection malware countermeasures to address malware infection mechanisms.
c. Propose where within the architectures of organization’s information systems where it might be most effective to provide protection from malware.
d. Debug a system (network, computer, or application) for the presence of malware.
e. Use techniques for safely isolating malware samples from infected systems and classifying the sample.

ITE-CSP-11 Mitigation and recovery

a. Discuss a risk mitigation and incident recovery plan.
b. Perform a mitigation of a malware infection on an enterprise client and an enterprise server.
c. Document 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. Document examples of the steps taken after a credential is lost or compromised.
f. Describe how supply chain risks could be reduced.

ITE-CSP-12 Personal information

a. Make sense of the terms Personal Information, Personally Identifiable Information, De-Identification, Anonymization, Pseudonym, Masking, and Unmasking.
b. Describe how the Fair Information Practices apply to personal information and the manner in which online entities collect and use personal information.
c. Classify several categories of personal information according to privacy and disclosure risk.
d. Contrast policies for collecting, processing, storing, sharing, and disposing of personal information.
e. Illustrate the role and limitations of encryption for protecting personal information.
f. Make sense of policies and technologies for isolating personal data from enterprise data.
g. Analyze approaches for controlling access to personal information.

ITE-CSP-13 Operational issues

a. Show how one determines the exposure and plans for the recovery of a lost laptop and mobile device.
b. Document standards that apply to an organization’s information security posture.
c. Evaluate potential vendors with respect to their security offerings.
d. Make meaning of emerging threats, vulnerabilities and mitigations.
e. Design a continuing education program.
f. Make sense of the challenges of recruitment, retention and retaining of security personnel.
g. Suggest and implement digital currency extensions using relevant scripting techniques (colored coins paradigm)

ITE-CSP-14 Reporting requirements
a. Document legal and regulatory requirements for sharing of threat and breach information.
b. Contrast different vulnerability disclosure policies, including “full disclosure,” and “responsible disclosure.”
c. Make sense of the concept of privacy breach versus security breach and the governing rules that apply to both types of breach.

ITE-GPP Global Professional Practice

ITE-GPP-01 Perspectives and impact
a. Describe the nature of professionalism and its place in the field of information technology.
b. Contrast between ethical and legal issues as related to information technology.
c. Describe how IT uses or benefits from social and professional issues.

ITE-GPP-02 Professional issues and responsibilities
a. Contrast the professional context of information technology and computing and adherence to ethical codes of conduct.
b. Describe and critique several historical, professional, ethical, and legal aspects of computing.

ITE-GPP-03 IT governance and resource management
a. Analyze the expanding role of IT governance and its effect on organizations.
b. Be aware of management issues in IT governance.
c. Compare and contrast organizational cultures and their impact on IT governance.
d. Justify the appropriate resources needed to administer the system.
e. Contrast several alternative vendors of system resources.
f. Develop naming conventions for the resources in a system.
g. Create and justify several appropriate policies and procedures to manage resources in a system.

ITE-GPP-04 Risk identification and evaluation
a. Analyze the role of risk to an organization and ways to identify key risk factors.
b. Evaluate various risks and appropriate actions.
c. Design and build a risk matrix.

ITE-GPP-05 Environmental issues
a. Analyze and critique ways to develop green IT policies, standards and learn to identify green IT.
b. Contrast several frameworks for green computing.
c. Describe several uses of green computing for improving energy efficiency.

ITE-GPP-06 Ethical, legal and privacy issues
a. Evaluate the role of legal, ethical and privacy issues within IT as it relates to organizations.
b. Reflect on whether existing laws need modification to keep up with technology.
c. Model a computer use policy that includes privacy, legal and ethical considerations for all employees.
d. Contrast ethical algorithms with algorithms that are ethically neutral.

ITE-GPP-07 Intellectual property
a. Describe the foundations of intellectual property.
b. Critique several transnational issues concerning intellectual property.
c. Distinguish among employees, contractors, and consultants and the implications of each status.
d. Compare software patents and contrast with other forms of intellectual property protection.

ITE-GPP-08 Project management principles
a. Describe the key components of a project plan.
b. Show the importance of a cost/benefit analysis to the successful implementation of a project plan.
c. Evaluate appropriate project planning and tracking tools.
d. Illustrate how to identify the lessons learned in a project closeout and review session.

ITE-GPP -09 Communications
a. Evaluate several strategies for effective professional communication in writing and in speaking.
b. Create well-organized technical reports that are structured according to acceptable standards.
c. Analyze and describe the role of communications within IT as well as in building relationships with the organizations.
d. Illustrate several essential skills for communicating within a team environment.

ITE-GPP-10 Teamwork and conflict management
a. Analyze several skill-sets needed to function effectively in a team environment.
b. Contrast several ways in which industry approaches teamwork toward a common goal.
c. Describe and critique several ways that conflict management aids in building stronger teams.

ITE-GPP-11 Employability skills and careers in IT
a. Evaluate viable skill sets essential to a career in IT.

b. Illustrate the elements of a successful technical resume.
c. Reflect on the need for industry experience within the IT field.
d. Compare the important elements needed for a strong interview for an IT position.

ITE-GPP-12 Information systems principles
a. Critique ways in which information systems supports organizational requirements.
b. Describe the system development life cycle, its phases, and models.
c. Evaluate the effectiveness and efficiency of a system.
d. Contrast several high-level IT strategies to avoid obstacles to achieve organizational goals.

ITE-IMA Information Management

ITE-IMA-01 Perspectives and impact
a. Describe how data storage and retrieval has changed over time.
b. Justify the advantages of a database approach compared to traditional file processing.
c. Describe how the growth of the Internet and demands for information for users outside the organization (customers and suppliers) impact data handling and processing.
d. Tell a brief history of database models and their evolution.

ITE-IMA-02 Data-information Concepts
a. Describe the role of data, information, and databases in organizations.
b. Compare and use key terms such as: information, data, database, database management system, metadata, and data mining.
c. Illustrate data quality, accuracy and timeliness, and explain how their absence will impact organizations.
d. Describe mechanisms for data collection and their implications (automated data collection, input forms, sources).
e. Describe basic issues of data retention, including the need for retention, physical storage, backup and security.

ITE-IMA-03 Data modeling
a. Design Entity Relationship diagrams based on appropriate organizational rules for a given scenario.
b. Describe the relationship between a logical model and a physical model.
c. Evaluate importance of database constraints.
d. Design a physical model for the best performance including impact of normalization and indexes.
e. Compare and contrast the differences and similarities between the relational and the dimensional data modeling (OLTP vs OLAP).

ITE-IMA-04 Database query languages
a. Create, modify and query database objects using the Structured Query Language (SQL).
b. Perform filtering and sorting data using various clauses including where, order by, between, like, group by and having.
c. Use joins to select data across multiple tables.
d. Use embedded SQL queries.
e. Perform calculations in a query using calculated fields and aggregate functions.
f. Create updatable and non-updatable views.

ITE-IMA-05 Data organization architecture
a. Demonstrate select, project, union, intersection, set difference, and natural join relational operations using simple example relations provided.
b. Compare and contrast relational databases concepts and non-relational databases including object-oriented, XML, NewSQL and NoSQL databases.
c. Express the relationship between functional dependencies and keys and give examples.
d. Evaluate data integrity and provide examples of entity and referential integrity.
e. Analyze how data fragmentation, replication and allocation affect database performance.

ITE-IMA-06 Special-purpose databases
a. Describe major concepts of object oriented, XML, NewSQL and NoSQL databases.
b. Demonstrate an understanding of online analytical processing and data warehouse systems.
c. Describe methods of data mining and what insights may be gained by these methods.

ITE-IMA-07 Managing the database environment
a. Contrast and compare data administration and database administration.
b. Describe tasks commonly performed by database administrators.
c. Create and manage database users, roles and privileges.
d. Consider the concept of database security and backup/recovery.
e. Evaluate the importance of metadata in database environment.

ITE-IST Integrated Systems Technology

ITE-IST-01 Perspectives and impact

a. Describe how integrating various modules can produce a working system.
b. Describe how integration is an important function of all IT professionals.

ITE-IST-02 Data mapping and exchange

a. Produce a definition for the term, metadata.
b. Describe how ASCII, EBCDIC, and Unicode are used to encode data, and show how each should be used.
c. Describe how XML and the document object model are being used to integrate and exchange data between systems.
d. Use DTD to create a document definition for a data structure. Given a DTD for data structure, create an XML document with real data.
e. Describe how XSL, XSLT and XPath are used to transform data streams.

ITE-IST-03 Intersystem communication protocols

a. Describe how different types of architectures must be considered for integrating systems.
b. Demonstrate 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. Demonstrate 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 demonstrate how they work. Illustrate the protocol used by one messaging service (e.g. JMS).
f. List the commonly used low level data communications protocols (e.g., RS232), describe how to know when each protocol should be used, and illustrate the protocol for one low-level communication protocol.

ITE-IST-04 Integrative programming

a. Describe how design patterns are useful in integrative programming.
b. Evaluate the motivation for using each of the following design patterns: MVC, singleton, factory method, façade, proxy, decorator, and observer.
c. Describe how a programming interface is used in programming, and illustrate with an example of where the use of a programming interface simplified the development of a system.
d. Define the concept of inheritance and describe how it can be applied to encourage code reuse.
e. Design an abstract class and use inheritance to create a class that extends the abstract class.
f. Design, develop and test an application that uses the abstract class.

ITE-IST-05 Scripting techniques

a. Describe how scripting languages are 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

a. Contrast evidence-based security vs. code access security.
b. Define and evaluate several goals of secure coding.
c. Justify the 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-NET Networking

ITE-NET-01 Perspectives and impact

a. Describe networking and the research scope of networking study.
b. Identify some components of a network.
c. Name several 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 several contributors to networks and relate their achievements to the area.

ITE-NET-02 Foundations of networking

a. Identify several current standards (e.g., RFC's and IEEE 802) and describe 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. Analyze why different technologies are deployed in different contexts of networking, such as topology, bandwidth, distance, and number of users.
d. Express the basic components and media of network systems and distinguish between LANs and WANs.
e. Describe 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. Exhibit 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
a. Show how the 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
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. Illustrate some networking and internetworking devices such as repeaters, bridges, switches, routers, and gateways.
e. Recognize network topologies such as mesh, star, tree, bus, ring, 3-D torus.
f. Contrast connection-oriented services with connectionless services.
g. Teach network protocol features such as syntax, semantics, and timing.
h. Be aware of 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. Evaluate the operation principles of some main protocols, such as FTP and SNMP.
k. Identify network standards and standardization bodies.

ITE-NET-05 Routing, switching, and internetworking
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. Describe 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
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. Illustrate several roles and responsibilities of clients and servers for a range of possible applications.
d. Select several 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 several web technologies such as dynamic HTML and the client-side model, server-side model.
h. Describe several characteristics of web servers such as handling permissions, file management, capabilities of common server architectures.
i. Use the support tools for website creation and web management.
j. Design the architecture and services of email systems.
k. Describe 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. Solve the problem of distributing content, the architecture of content distribution network and peer-to-peer network.

ITE-NET-07 Network management
a. Propose several 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. Exhibit the concepts of domain names and domain name systems (DNS).
g. Describe the dynamic host configuration protocol (DHCP).
h. Describe several issues related to internet service providers (ISPs).
i. Illustrate several quality-of-service issues such as performance and failure recovery.
j. Describe ad hoc networks.
k. Teach troubleshooting principles and techniques related to networks.
l. Describe management functional areas related to networks.

ITE-PFT Platform Technologies

ITE-PFT-01 Perspectives and impact

a. Describe how the historical development of hardware and operating system computing platforms produced the computing operating systems we have today.

ITE-PFT-02 Operating systems

a. Describe how the components and functions of an operating system work together to provide a computing platform.
b. Demonstrate the ability to use both Windows and Unix-class systems.
c. Describe how the similarities and differences between Windows and Unix-class systems provide different advantages for these computing platforms.
d. Demonstrate the main benefits of using scripts to perform operating systems tasks by automating a computing task.

ITE-PFT-03 Computing infrastructures

a. Analyze the power requirements for a computer system.
b. Justify the need for power and heat budgets within an IT environment.
c. Describe how the various types of servers meet different organizational requirements.
d. Justify the need for hardware and software integration.

ITE-PFT-04 Architecture and organization

a. Describe how numbers and characters are represented in a computer.
b. Produce 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. Produce a definition for each of these terms: bus, handshaking, serial, parallel, data rate.

ITE-PFT-05 Application execution environment

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

ITE-SPA System Paradigms

ITE-SPA-01 Perspectives and impact

a. Contrast system integration and system architecture.
b. Explain the system integration from the organizational perspective.

ITE-SPA-02 Requirements

a. Compare the various requirements modeling techniques.
b. Contrast between non-functional and functional requirements.
c. Demonstrate the structure of a detailed use case.
d. Express a use case based on relating functional requirements.
e. Illustrate the types of event flows in a use case and under which conditions they occur.
f. Describe how requirements gathering complements a system development lifecycle.
g. Describe how use cases drive testing throughout a system lifecycle.

ITE-SPA-03 System architecture

a. Demonstrate "architecture" in the context of system integration and architecture reflecting IEEE Standard 1471.
b. Justify how complex systems can be represented using architectural views and how this facilitates system evolution over time.
c. Describe how some specific architectural views relate to the system lifecycle.
d. Contrast the SOA, Zachman Framework, ITIL, COBIT, and ISO 20,000 architectural frameworks.
e. Describe how modeling tools support the description and management of architectural views with examples.

ITE-SPA-04 Acquisition and sourcing

a. Contrast between build and buy in software and hardware acquisition.

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

ITE-SPA-05 Testing and quality assurance
a. Express different ways for current testing standards.
b. Demonstrate the various components of usability testing.
c. Express different ways to execute and evaluate an acceptance test.

ITE-SPA-06 Integration and deployment
a. Express different ways for middleware platforms.
b. Demonstrate the advantages and disadvantages of some middleware platforms.
c. Justify major considerations for the selection of an enterprise integration platform.
d. Express different ways of integration using the “wrapper” approach.
e. Express different ways of integration using the “glue code” approach.
f. Describe how a framework facilitates integration of components.
g. Describe how the data warehouse concept relates to enterprise information integration.
h. Describe how integration choices affect testing and evaluation.

ITE-SPA-07 System governance
a. Compare alternative vendors of systems resources and justify a selection.
b. Develop policies for a networked system in an application domain (e.g., health care organization).
c. Develop policies for a network that includes low capacity embedded devices (e.g., a smart home).
d. Develop a disaster recovery plan for a small enterprise.

ITE-SPA-08 Operational activities
a. Design and implement a user and group administrative structure that allows users to use system resources effectively.
b. Design and construct development resources regarding administrative policies for different types of users.
c. Develop and monitor project plans for major system administration activities.
d. Install, configure, and test appropriate software and other resources.
e. Install, configure, and test automated device management technologies.
f. Design and implement a backup and restore strategy for a system.

ITE-SPA-09 Operational domains
a. Describe the scope of each operational domain in a system.
b. Develop and justify policies for each domain that allow for smooth interaction between domains without sacrificing security.
c. Develop and justify resource allocation plans for various operational domains.

ITE-SPA-10 Performance analysis
a. Design and implement a backup and restore strategy for a system.
b. Test the veracity of a disaster recovery plan for a small enterprise.
c. Confirm the accuracy and completeness of a backup.

ITE-SWF Software Fundamentals

ITE-SWF-01 Perspectives and impact
a. Reflect on how the creation of software has changed our lives.
b. Synthesize how software has helped people, organizations, and society to solve problems.
c. Argue for several advantages on ways software has created new knowledge.

ITE-SWF-02 Concepts and techniques
a. Compare 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 maintaining programs and to generalize solutions.
d. Explain multiple levels of hardware architecture abstractions (processor, special purpose cards, memory organization, and storage) and software abstractions (source code, integrated components, running processes) involved in developing complex programs.
e. Create new programs by modifying and combining existing programs.

ITE-SWF-03 Problem-solving strategies
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
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. Demonstrate collaboration strategies that take into account multiple perspectives, diverse talents, sociocultural experiences.

ITE-SWF-05 Fundamental data structures
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. Decide on appropriate data structures for modeling a given problem.
d. Explain appropriateness of selected data structures.

ITE-SWF-06 Algorithm principles and development
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 appropriate mathematical concepts in programing: expressions, abstract data types, recurrence relations, and formal reasoning on algorithm's efficiency and correctness.
e. Evaluate empirically the efficiency of an algorithm.

ITE-SWF-07 Modern app programming practices
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-UXD User Experience Design

ITE-UXD-01 Perspectives and impact
a. Show 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 several modern high-tech computing technologies that present UXD challenges.
g. Describe several reasons for making UXD an essential part of the information technology discipline.

ITE-UXD-02 Human factors in design
a. Explain the conceptual terms for analyzing human interaction with products (e.g., affordance and feedback).
b. Analyze several 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 several ways cognitive and social principles apply to product design.
e. Illustrate several ways that physical aspects of product design affect usability.
f. Identify several 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
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. Design and justify a low-fidelity prototype for a system or product.
f. Design and justify a high-fidelity prototype for a system or product.
g. Demonstrate the advantages of user interface modalities other than windows, icons, menus and pointers in some situations.

ITE-UXD-04 Application domain aspects
a. Describe different types of interactive environments.

b. Describe several differences in developing user interfaces for different application environments and types of services.
c. Represent the connection between the design of a user interface and a model of user domain expertise.
d. Compare descriptions of cognitive models with the model names.
e. Propose cognitive models to the design of application user interfaces.
f. Argue for social psychology in the design of a user interface
g. Show how contextual, societal, cultural, and organizational factors can be applied in the design of a user interface.
h. Analyze an IT mediated service with several different user types and various stakeholders including a service provider.

ITE-UXD-05 Affective user experiences

a. Illustrate 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

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

ITE-UXD-07 Assistive technologies and accessibility

a. Describe several main principles for universal design.
b. Illustrate 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. Use 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. Propose an 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.
i. Describe the structure and components of an assistive technology.

ITE-UXD-08 User advocacy

a. Express 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. Propose appropriate user tasks for an application under consideration.
e. Describe the effect of socialization on the effectiveness of an application interface.
f. Demonstrate the importance of evaluating the impact of proposed system changes on the user experience.

ITE-WMS Web and Mobile Systems

ITE-WMS-01 Perspectives and impact

a. Describe how the world-wide web has impacted people's lives over time.
b. Illustrate the growth and changes in mobile devices and applications over time.

ITE-WMS-02 Technologies

a. Describe the role of HTTP and HTTPS in the context of web applications.
b. Build a simple web site that
    - organizes information effectively
    - uses valid HTML and CSS
    - applies appropriate web standards from standards bodies such as W3C
c. Develop a web or mobile application that
    - uses industry-standard technologies
    - integrates serialized data in a structured format such as XML or JSON both synchronously and asynchronously
    - validates data inputs on the client- and server-side as appropriate,
    - uses cookies
    - reads or modifies data in a server-side database
    - uses JavaScript
d. Express the constraints involved in state management (cookies, query strings, sessions) in the web and mobile context.
e. Contrast client-side with server-side security issues.

ITE-WMS-03 Digital media

a. Compare characteristics such as color depth, compression, codec, and server requirements for
    - graphic media file formats
    - streaming media formats

b. Propose a graphic file type for a given set of image characteristics.
c. Provide metaphors for issues involved in deploying and serving media content.

ITE-WMS-04 Applications concepts

a. Express constraints that mobile platforms put on developers, including the performance vs. power tradeoff.
b. Contrast mobile programming, web programming, and general purpose programming.
c. Apply principles of UXD to enhance the user experience of a web site or mobile application.
d. Evaluate the design and architecture of a web or mobile system, including issues such as design patterns (including MVC), layers, tradeoffs between redundancy and scalability, state management, and search engine optimization.

ITE-WMS-05 Development tools and frameworks

a. Use industry-standard tools and technologies for web and mobile development.
b. Argue the advantages and disadvantages of development frameworks for web and mobile development.
c. Use a development framework such as jQuery, Angular, Laravel, ASP.NET MVC, Django, or WordPress.
d. Use collaboration tools such as GitHub to work with a team on a web or mobile application.

ITE-WMS-06 Vulnerabilities

a. Illustrate browser security models including same-origin policy and thread models in web security.
b. Describe how authentication, secure certificates, and secure communication can be used in web sessions.
c. Instruct others on common types of vulnerabilities and attacks in web and mobile applications, such as
    - using web page graphics as web beacons
    - using cookies to compromise privacy
    - denial of service attacks
    - cross-site scripting attacks
    - SQL injection attacks
d. Secure a web or mobile application and defend against common attacks using techniques such as
    - client-side security capabilities
    - public key encryption
    - security certificates
    - safely persisting user logins (such as "remember me" functionality)
e. Use accepted standards to ensure that user input on web pages do not affect server-side processes.

ITE-WMS-07 Social software

a. Illustrate the difference between asynchronous and synchronous communication on the web.
b. Contrast the characteristics of various web- and mobile-based communication media.

B.2 Supplemental IT Domains

ITS-ANE Applied Networks

ITS-ANE-01 Proprietary networks

a. Describe several 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

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 several major technologies used in network communications.
h. Design, develop and test a socket program that communicates between several 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

a. Describe the meaning of a routing protocol.
b. Contrast an IPv4 subnet with an IPv6 subnet.
c. Demonstrate 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

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 several main characteristics of mobile IP and show 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. Illustrate several security issues related to mobile computing.
j. Describe performance issues related to mobile computing.

ITS-ANE-05 Wireless networks

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

ITS-ANE-06 Storage area networks

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 several 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

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. Express 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-CCO Cloud Computing

ITS-CCO-01 Perspectives and impact

a. Recognize what it means when IT is defined as "in the cloud".
b. Decide 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. Argue the reasons why cloud computing is an essential part of information technology.

ITS-CCO-02 Concepts and fundamentals

a. Demonstrate 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. Be aware of several privacy legislation examples as they relate to cloud computing.
e. Contrast private sector and public sector requirements.
f. Analyze the organizational drivers for using cloud services including risk/benefit assessment (i.e. cloud first).

ITS-CCO-03 Security and data considerations

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

ITS-CCO-04 Using cloud computing applications

a. Compare the differences between an internal application and a cloud application.
b. Contrast the advantages and disadvantages of cloud applications.
c. Match descriptions of cloud service types with cloud service names.
d. Propose several samples of risk/ benefit assessments when selecting applications.
e. Decide which application characteristics will not, or should not, run in the cloud.

ITS-CCO-05 Architecture

a. Be aware of architecture principles of cloud computing service delivery.
b. Contrast cloud architectures to outsourcing (i.e. hosted) and shared services models.
c. Critique common change control guidelines and standards as they relate to cloud services.
d. Propose several ways of measuring cloud service performance and the importance of service level agreements.
e. Recognize the challenges of 'big data' analytics in the cloud.
f. Contrast single cloud vs multiple cloud deployment models.

ITS-CCO-06 Development in the cloud

a. Compare developing systems in cloud environments as compared to traditional environments.
b. Document on-demand, self-service design requirements.
c. Contrast the use of synchronous vs. asynchronous transactions.
d. Analyze criteria for choosing coupled or de-coupled system integration.
e. Build and deploy several basic cloud applications.
f. Design an interface for a cloud application to be used on a smartphone.

ITS-CCO-07 Cloud infrastructure and data

a. Compare the infrastructure differences between public cloud computing, private cloud computing and hybrid models.
b. Argue how virtualization is a driving principle behind cloud computing.
c. Illustrate how rapid elasticity is a characteristic of cloud computing infrastructure.
d. Contrast the desirable and undesirable characteristics of cloud data management.
e. Reflect on how emerging technologies could change the design of cloud services (i.e., IoT).

ITS-CEC Cybersecurity Emerging Challenges

ITS-CEC-01 Case studies and lessons learned

a. Describe how the deployment of a new technology impacts cybersecurity.
b. Describe how law enforcement is impacted by the introduction of new cybersecurity technologies.
c. Show how a cybersecurity event had global reach, such as the DigiNotar incident or the SSL Heartbleed vulnerability.
d. Tell a story of a cybersecurity case studies describing the impact and lessons learned from the case.

ITS-CEC-02 Network forensics

a. Use tools to identify information that can be examined in a network.
b. Perform a network inventory.
c. Compare active and passive approaches to network forensics.
d. Describe how a man-in-the-middle attack can reveal the contents of an encrypted network communication.
e. Employ surveillance mechanisms to discover network intrusion.

ITS-CEC-03 Stored data forensics

a. Show where data is stored in a complex system.
b. Use a criminal investigative technique in a computer forensic investigation scenario.
c. Exhibit digital evidences for presentation in court.
d. Find 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

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. Use forensic tools specific to major mobile operating systems.
d. Unlock and root mobile devices.
e. Describe how to detect or reveal encrypted contents.

ITS-CEC-05 Cloud security

a. Make sense of the different security issues stemming from the use of platform as a service, infrastructure as a service, and software as a service.
b. Argue the value of Risk and Authorization Management programs (like FedRAMP) and the key processes used in those programs.
c. Contrast the security benefits and risks of cloud storage systems.
d. Describe how authentication strategies are implemented for users of cloud systems.
e. Propose forensic options for analyzing cloud-based systems.
f. Analyze auditing and recovery options for cloud servers.

ITS-CEC-06 Security metrics

a. Document requirements of security metrics.
b. Propose data that supports the creation of metrics.
c. Perform a security measurement to a network resource.
d. Analyze the role of continuous monitoring in a security practice.
e. Describe how security metrics can be used to detect compliance and risk issues.

ITS-CEC-07 Malware analysis

a. Use a Binary analysis tool.
b. Use a Disassemblers tool.
c. Use a Debugger tool.
d. Use a sandbox.
e. Compare static and dynamic analysis.
f. Illustrate proper laboratory procedures for handling malware.
g. Analyze whether a specific malware detector would identify a malware sample.

ITS-CEC-08 Supply chain and software assurance

a. Illustrate a hardware supply chain.
b. Illustrate a software supply chain.
c. Propose security considerations that should be evaluated for each stage in the lifecycle of a product.
d. Be aware of secure software development including the use of safe language, static analysis of software, and dynamic software testing.
e. Exhibit several common defects, bugs, and logic flaws in software.

ITS-CEC-09 Personnel and human security

a. Describe how an insider can intentionally and unintentionally reduce or affect an organization's security posture.
b. Make sense of the limits a background check is in screening an organization's employees.
c. Illustrate how to recognize phishing and spear phishing.
d. Compare the benefits with the risks of a 'bring your own device' (BYOD) program.
e. Tell a story about dangerous places on the web and how surfing one of them can have a negative impact on privacy or security.
f. Tell a story about how a social engineering attack can be designed using data posted on social media.

ITS-CEC-10 Social dimensions

a. Discuss the trade-off between utility and risk of cloud computing, file sharing, and peer-to-peer services.
b. Make sense of the impact of IT systems on privacy.
c. Make meaning of the inherent tension between the concepts of personal privacy, accountability, and deterrence related to cybersecurity events.
d. Describe how crowdsourcing techniques such as big data mining impacts data confidentiality, integrity, and availability.

ITS-CEC-11 Security implementations

a. Analyze the options for enterprise malware detection.
b. Contrast the effectiveness and costs of malware detection with application whitelisting.
c. Make sense of the limitations 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 organization and a large-scale enterprise.
f. Recognize "security containers" and identify their limitations and usability failings with respect to mobile devices.
g. Provide a thorough security analysis of digital currency implementation.
h. Design and develop digital currency e-commerce applications using relevant development tools and protocols (e.g., bitpay insight, bitcore, cosign)

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

a. Make meaning of the terms CPS and IoT and why they are often used interchangeably and identify definitions that indicate the differences between them.
b. Recognize the protocols and networks typically used to connect CPS and IoT devices to networks.
c. Describe how security mechanisms are 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. Describe how the handling and storage of data delivered by IoT devices offers challenges to security & privacy.

ITS-DSA Data Scalability and Analytics

ITS- DSA-01 Perspectives and impact

a. Discuss the emerging field of data science.
b. Identify 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 Large-scale data challenges

a. Define and describe large-scale data challenges volume, variety, velocity and veracity.
b. Define and describe challenges of large scale data analytics in diverse sectors such as sensor networks, finance, retail, genomics and social media.
c. Compare 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

a. Discuss 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

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

ITS-DSA-05 Data governance

a. Identify the importance of data governance for managing large-scale data.
b. Identify 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 regulatory compliance rules and regulations applicable to data management.

ITS-DSA-06 Application

a. Define an organizational problem as an analytics problem.
b. Describe how to best apply large-scale analytics methods and techniques in addressing strategic organizational 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 organizational performance using case studies.

ITS-IOT Internet of Things

ITS-IOT-01 Perspectives and impact

a. Contrast the internet of things with the web of things, with industrial internet, with pervasive computing, and with smart systems.
b. Express the historical stages and growing evolution of the IoT concept.

ITS-IOT-02 IOT architecture

a. Contrast IoT architectural domains.
b. Design an architectural framework for an IoT environment.
c. Illustrate the challenges in defining the architecture for different IoT applications.

ITS-IOT-03 Sensor and actuator interfacing

a. Compare strategic approaches to develop elements for a multimedia IoT system.
b. Illustrate the effect of signal processing concepts on speech applications and in basic sound generation applications.
c. Contrast the differences between analog signal processing, continuous-time signal processing, discrete-time signal processing, and digital signal processing.
d. Contrast signal processing devices to include filters, samplers, signal compressors, and digital signal processors.
e. Illustrate ways to interface an IoT component to sensors and actuators.

ITS-IOT-04 Data acquisition

a. Contrast data acquisition and signal conditioning.
b. Illustrate the effect of IoT on multiplexing and sampling theory.
c. Express several ways to use IoT sensors for electrical, temperature, and strain measurements.
d. Express several ways to reduce and isolate signal noise.
e. Illustrate the machine-to-machine (M2M) communication, which is a major component of the IoT portfolio of technologies.
f. Demonstrate several security issues and challenges of collaborative data acquisition in IoT.

ITS-IOT-05 Wireless sensor networks

a. Demonstrate on wireless sensor networks (WSNs) vis-à-vis their protocols and algorithms from a historical perspective.
b. Contrast stack-based approaches and topology-based approaches for the integration of wireless sensor networks.
c. Illustrate the IoT commonalities between health-care issues, assisted and enhanced-living issues, industrial and production monitoring issues, and control network issues.

ITS-IOT-06 Ad-hoc networks

a. Express the design and implementation issues related to ad hoc networks and suggest available solutions.
b. Contrast the difference between the following routing techniques: proactive routing, reactive routing, hybrid routing, and position-based routing.
c. Demonstrate several clustering mechanisms in ad hoc networks.
d. Analyze quality-of-service and scalability issues in the context of ad-hoc networks.
e. For mobile ad hoc networks (MANET), contrast between vehicular ad hoc networks (VANETs), smart phone ad hoc networks (SPANs), and internet based mobile ad-hoc networks (iMANETs).

ITS-IOT-07 Automatic control

a. Illustrate the elements of classical control theory as applied to the control of aircraft and spacecraft.
b. Contrast the properties of positive feedback with negative feedback.
c. For the functions of automatic control, contrast the differences between measurement, comparison, computation, and correction.
d. Represent several common elements of automatic control in systems as applied to measurement, error detection, and final control element.
e. Demonstrate several basic linear design techniques as applied to spacecraft and aircraft.

ITS-IOT-08 Intelligent information processing

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

ITS-IOT-09 IoT application and design

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

ITS-MAP Mobile Application

ITS-MAP-01 Perspectives and impact

a. Describe the history of mobile development and mobile applications.
b. Demonstrate the global scope of the processes of implementing a mobile application.
c. Describe and compare several development environments for mobile applications.

ITS-MAP-02 Architectures

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

ITS-MAP-03 Multiplatform mobile application development

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

ITS-MAP-04 Servers and notifications

a. Describe protocol suites.
b. Illustrate 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

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

ITS-MAP-06 Views and gestures

a. Illustrate each element about views.
b. Describe text and typesetting units.
c. Express and compare several ways to improve picture presentation.
d. Demonstrate several methods to improve gesture definition and its application.

ITS-MAP-07 Interface implementations

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

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

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

ITS-MAP-09 2D graphic and animation

a. Express several basic concepts of 2D graphic and animation.
b. Create graphics on different mobile platforms.
c. Design a dynamic graphic transformation for animation.
d. Design 2D graphics and animation on several mobile devices using different operating systems.

ITS-SDM Software Development and Management

ITS-SDM-01 Process models and activities

a. Illustrate the software development process.
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.

ITS-SDM-02 Platform-based software development

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 by using library and other service interfaces (e.g., APIs) specific to the user's platform.
c. Explain the differences among platform-specific development and general-purpose programming.
d. Test some constraints that platforms impose on development.

ITS-SDM-03 Tools and services

a. Show how modern tools and services improve efficiency and effectiveness of developers working in teams and on systems with various challenges (e.g., size, constrained by time or resources, legacy code).
b. Select and use 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

a. Argue 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. Assess development effort and participate in process improvement by tracking commitments and managing project quality.
f. Use project metrics to monitor a project's progress.

ITS-SDM-05 Deployment, operations, and maintenance

a. Use 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

ITS-SRE-01 Social Context of Computing

a. Show the importance of the social context of IT and adherence to ethical codes of conduct.
b. Describe the importance of green computing strategies.
c. Contrast several historical, social, professional, ethical and legal aspects of e-computing.
d. Describe several ways teamwork integrates throughout IT and supports an organization.
e. Justify how computing alters the modes of interaction between persons.
f. Describe some parameters needed to design an ethical algorithm.

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

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

ITS-SRE-03 Government role and regulations

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

ITS-SRE-04 Global challenges and approaches

a. Critique IT approaches to reduce energy consumption such as thin client solutions as well as on a global scale.
b. Describe the employment of environmental computing practices in the life cycle of IT applications and system design.
c. Evaluate organizational green computing performance metrics, recycling practices, energy use and e-waste reduction.
d. Describe reasons for having etical algorithms in robotics and artificial intelligence.

ITS-SRE-05 Risk management

a. Evaluate the aspects of an organization 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. Analyze and describe steps to assess risks associated with security specified by accepted Security Standards.
d. Describe the costs associated with actions that can be taken to mitigate security risks.

ITS-SRE-06 Sustainable Computing
a. Be aware of common energy saving guidelines and standards (e.g. Energy Star international standard) and be aware of sensor and monitoring software used to track energy use.
b. Be aware of industry standards (e.g. advanced configuration and power (ACP) interface design and manufacturing of computer components for power savings).
c. Describe several techniques for the use of renewable energy sources (i.e. solar and wind power).
d. Show how workplace incentives will increase the implementation of green computing and computer hazardous material management.
e. Analyze and critique capital investment projects needed to continue stable energy delivery.

ITS-VSS Virtual Systems and Services

ITS-VSS-01 Perspectives and impact
a. Describe how virtualization creates an improved solution.
b. Compare a virtual machine to virtualization.
c. Compare a host machine to a virtual machine.
d. Demonstrate the role of the hypervisor.
e. Compare hypervisor on bare metal (VMware) and hypervisor running in an OS (Hyper-V, RHEV, OracleVM).

ITS-VSS-02 Implementation of virtualization
a. Analyze the types of situations where virtualization is an appropriate solution.
b. Contrast the advantages and disadvantages of virtualization in different application areas.
c. Document the different virtualization licensing issues for Windows, Linux and Max OSx operating systems.
d. Contrast virtualization of applications with clustering applications.

ITS-VSS-03 User Platform virtualization
a. Critique different user platform (i.e., desktops and devices) virtualization frameworks.
b. Contrast 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
a. Critique server virtualization platforms and licensing differences.
b. Contrast 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
a. Compare the differences between a physical and virtualized network.
b. Contrast 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
a. Contrast several different server cluster designs.
b. Describe how tools and techniques are 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
a. Explain how clustering software functions.
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. Illustrate application cluster concepts such as load balancing, failover, and node monitoring.

ITS-VSS-08 Storage
a. Contrast the different storage environments and describe how they function.
b. Contrast 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. Illustrate a tiered storage environment.

Appendix C: Traditional Four-year IT Curricula Examples

This appendix to this 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 geographic and institutional needs as well as program priorities.

Country or Region	Appendix Section
United States	C.4
Saudi Arabia and Middle East	C.5
China	C.6

C.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

C.1.1 Course Time Conventions

To clarify the identification of levels, and implementations, course numbers reflect ways that identify the level at which it appears in the program. Thus, a course numbered MTH 100 is a course commonly taught in the first year (at the freshman level). Likewise, PHY 200 is a course commonly taught in the second year (at the sophomore level); IT 300 is a course commonly taught in the third year (at the junior level); and course IT 400 is commonly taught in the fourth year (at the senior level). For information technology and computing courses, course codes identify the country curriculum in which they appear. Thus, a course coded CMPC is a computing course commonly taught in China, while ITU is an information technology course commonly taught in Untied States.

To provide ease of comparison, all curricula implementations appear as a set of courses designed for a system in which a semester provides 15 weeks of lecture and laboratory including the equivalent of one week for examinations, vacations, and reading periods. 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 some semester credits, according to the number and types of formal activities within a given week, determined as follows.

- Lecture hours: presentation of material in a classroom setting
    - 1 credit = One, 1-hour lecture per week for 15 weeks (including exams)
- Laboratory hours: formal experimentation in a laboratory setting
    - 1 credit = One, 3-hour or 2-hour laboratory session per week for 15 weeks (including exams

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 lectures per week for 15 weeks = 45 lecture hours (including exams)
- *1-credit laboratory course*:
  Either one 2-hour laboratory session per week for 15 weeks = 30 lab hours (including exams)
  or one 3-hour laboratory session per week for 15 weeks = 45 lab hours (including exams)
- *3-credit course with two lectures and one lab session each week*:
  2 lecture hours per week for 15 weeks = 30 lecture hours (including exams)
  One 2-hour or 3-hour lab per week for 15 weeks = 30 or 45 lab hours (including exams)
- *3-credit project design course*:
  1 classroom meeting per week for 15 weeks = 15 lecture hours (including exams)
  2, 2-hour or 3-hour lab per week for 15 weeks = 60 or 90 lab hours (including exams)

C.1.2 Mapping of 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 row, labeled *Subdomains Covered*, lists the subdomains from each domain covered by this sample curriculum. Since all the sample curricula have complete domain core coverage, the bottom row contains all the subdomains from the IT essential domains. The sample curricula do not cover all the supplementary domains and the coverage shown does not convey a priority or recommended coverage.

C.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 a laboratory component, 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.

C.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.

C.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.

C.4 Typical IT Curriculum – United States

Information Technology Program
Administered by a School of Technology

C.4.1 Program Goals and Features

This program leads to a bachelor's degree in information technology, as offered by a program housed in a school of technology, in a college of engineering and technology. Some of the required courses occur in computing departments. This program usually has multi-course sequences in programming, web systems, databases, networking, human-computer interaction, and cybersecurity. This program has an orientation directed 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 can be competitive in any general area of applications of computers.

C.4.2 Summary of Requirements

This program of study contains 3 required computing courses (9 credits), 11 required information technology (IT) courses (36 credits), 3 elective IT courses (9 credits), and 5 elective courses (15 credits) in a computer application depth area or a concentration. The IT elective courses may come from any non-required IT courses; the depth area electives may come from any area of computer applications. Laboratory time occurs 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	***Credits***
Required information technology	36
Information technology electives	10
Concentration or Application domain electives	18
Mathematics	7
Required computing	9
Natural science (physics, biology)	9
English composition, humanities, social sciences	21
Innovation, global, ethics	4
Free electives	6
Total Credits	**120**

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

C.4.3 Four-Year Model for United States Curriculum

ITU: Offered by an information technology or related department
CMPU: Offered in a computing department

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
ITU 101	IT Cornerstone	3	ITU 102	Intro to Computer Systems	3
CMPU 101	Intro to Computer Programming	3	CMPU 201	Foundations of Computing	3
Math 120	Calculus 1	4	Physics 120	Physics 1	3
Am Htg	American Heritage	3	Writing 150	Composition	3
	Total Credits	**13**		*Total Credits*	**12**
Semester 3			**Semester 4**		
ITU 201	Web-based IT	4	ITU 202	Computer Architecture	3
Phys 121	Physics 2	3	CMPU 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 Credits	**13**		*Total Credits*	**12**
Semester 5			**Semester 6**		
ITU 402	IT Seminar	0.5	ITU 402	IT Seminar	0.5
ITU 301	Database Principles & Applications	3	ITU 302	Operating systems	3
ITU xxx	Digital Communications	4	ITU 303	Networks	3
TKU 201	Globalization; Ethics	3	ITU 304	Human Comp Interact	3
Engl 301	Technical Writing	3		Concentration or applic domain elective	3
	Concentration or applic domain elective	3		Concentration or applic domain elective	3
	Total Credits	**16.5**		*Total Credits*	**15.5**
Semester 7			**Semester 8**		
ITU 451	Senior Capstone I	3	ITU 447	Senior Capstone II	3
ITU xxx	IT Tech Elect	3	ITU xxx	IT Tech Elect	3
ITU 420	Info Assurance & Security	3	Econ 110	Principles of Economics	3
ITU 402	IT Seminar	0.5	ITU 402	IT Seminar	0.5
	Concentration or applic domain elective	3		Arts or Letters	3
	Concentration or applic domain elective	3		Concentration or applic domain elective	3
	Total Credits	**15.5**		*Total Credits*	**15.5**

C.4.4 Mapping of Information Technology Curricular Framework to United States Curriculum

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

Essential Domains / *Courses*	**NET**	**WMS**	**IMA**	**SWF**	**PET**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
ITU 101	1	1	1	1	1	1	1	1	1	
ITU 102										
ITU 201		2-7				2-6				
ITU 202								2-6		
ITU 301			2-7							
ITU 302					2-5					
ITU 303	2-7									
ITU 304							2-8			
ITU 401								7-10		
ITU 402										2, 11
ITU 420									2-14	
ITU 451										3, 4, 6-10
ITU 452										12
CMPU 101				1-4						
CMPU 201				5-7						
CMPU 202										
TKU 201										1, 5
Subdomains Covered	1-7	1-7	1-7	1-7	1-5	1-6	1-8	1-10	1-14	1-12

C.4.5 United States Curriculum – Course Summaries

ITU 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
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-NET 1, ITE-WMS 1, ITE-IMA 1, ITE-SWF 1, ITE-PET 1, ITE-IST 1, ITE-UXD 1, ITE-SPA 1, ITE-CSP 1.

ITU 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: CMPU 101
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: -

ITU 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: ITU 101, CMPU 101
Credits: 4 *Lecture Hours*: 45 *Lab Hours*: 30
IT Domain Coverage: ITE-IMA 2-7, ITE-IST 2-6

ITU 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: ITU 102, CMPU 201
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-SPA 2-6

ITU 301: Database Principles and Applications

Database theory and architecture; data modeling; designing application databases. Query languages, data security, database applications on the Web.
Prerequisite: CMPU 202
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-IMA 2-7

ITU 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: CMPU 101, ITU 202
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-PET 2-5

ITU 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: CMPU 202
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-NET 2-7

ITU 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: ITU 201
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-UXD 2-8

ITU 401: System Administration and Maintenance

Administration activities and domains for computing systems, including performance analysis, backup, and recovery.
Prerequisite: ITU 302
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-SPA 7-10

ITU 402: IT Seminar
Meet with IT professionals to learn about professional issues and responsibilities, employability skills, and careers in IT. Meet every two weeks for four semesters.
Prerequisite: Sophomore-level standing in program
Credits: 2 *Lecture Hours*: 30 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 2,11

ITU 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: ITU 301, ITU 302, ITU 303
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-CSP 2-14

ITU 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: ITU 301, ITU 302, ITU 303
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-GPP 3, 4, 6-10

ITU 452: Senior Project/Capstone II
Senior project design and integration. Second class of two-course sequence. Implementing design. Project management, teamwork, and presentations.
Prerequisite: ITU 451
Credits: 3 *Lecture Hours*: 15 *Lab Hours*: 60
IT Domain Coverage: ITE-GPP 12

CMPU 101: Introduction to Computer Programming
Introduction to object-oriented program design and development. Principles of algorithm formulation and implementation.
Prerequisites: None
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: Programming Assignments
IT Domain Coverage: ITE-SWF 1-4

CMPU 201: Foundations of Computing
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: CMPU 101
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: Programming Assignments
IT Domain Coverage: ITE-SWF 5-7

CMPU 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: CMPU 201
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: Programming Assignments
IT Domain Coverage: -

ITU 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
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 1, 5

C.5 Typical IT Curriculum – Saudi Arabia and Middle East

Information Technology Program
Administered by an Information Technology Department in Saudi Arabia or Middle East

C.5.1 Program Goals and Features

This program leads to a bachelor's degree in information technology, as offered by a traditional information technology (IT) department. One or more computing departments would offer computing foundation courses such as programming; the IT department teaches the remaining courses.

C.5.2 Summary of Requirements

This program of study contains 6 required computing (CMP) courses (22 credits) and 17 required information technology (IT) courses (51 credits). Flexibility derives from the four IT elective courses (12 credits), 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 could join an IT center as a full time for at least 8 weeks to pass the practical training course. This curriculum requires 44 courses, with credits distributed as follows.

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

C.5.3 Four-Year Model for Saudi Arabia and Middle East Curriculum

ITS: Offered by an information technology or related department
CMPS: Offered in a computing department

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

C.5.4 Mapping of Information Technology Curricular Framework to Saudi Arabia and Middle East Curriculum

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

Essential Domains / ***Courses***	**NET**	**WMS**	**IMA**	**SWF**	**PET**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
CMPS 104										
CMPS 106										
CMPS 140				1-4						
CMPS 141				7						
CMPS 220										
CMPS 242				5-6						
ITS 280	1	1	1		1	1	1	1	1	1
ITS 300							2-8			
ITS 301								2-6		
ITS 310									2-7	
ITS 315								7-10		
ITS 320			2-4							
ITS 331						2-6				
ITS 340	2-7									
ITS 360					2-5					
ITS 390		2-7								
ITS 410									8-14	
ITS 412										2-7
ITS 420			5-7							
ITS 490										6-10
ITS 491										8-11
ITS 492										3,4, 6-10
ITS 493										12
Subdomains Covered	1-7	1-7	1-7	1-7	1-5	1-6	1-8	1-10	1-14	1-12

C.5.5 Saudi Arabia and Middle East Curriculum – Course Summaries

CMPS 104: Discrete Structures
This course will introduce the student to a body of mathematical concepts essential for the proficiency in 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
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITM-DSC 1-12

CMPS 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: CMPS 104
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: -

CMPS 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
Credits: 4 *Lecture Hours*: 45 *Lab Hours*: 30
IT Domain Coverage: ITE-SWF 1-4

CMPS 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: CMPS 140
Credits: 4 *Lecture Hours*: 45 *Lab Hours*: 30
IT Domain Coverage: ITE-SWF 7

CMPS 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: CMPS 141, CMPS 106
Credits: 4 *Lecture Hours*: 45 *Lab Hours*: 30
IT Domain Coverage: -

CMPS 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: CMPS 141, CMPS 104
Credits: 4 *Lecture Hours*: 45 *Lab Hours*: 30
IT Domain Coverage: ITE-SWF 5-6

ITS 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
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-NET 1, ITE-WMS 1, ITE-IMA 1, ITE-PFT 1, ITE-IST 1, ITE-UXD 1, ITE-SPA 1, ITE-CSP 1, ITE-GPP 1.

ITS 300: Human-Computer Interaction
This course introduces 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; introduction and evaluation of user-centered design methods; introduction students to the contemporary technologies used in empirical evaluation methods.
Prerequisites: ITS 280
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-UXD 2-8

ITS 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: ITS 280
Credits: 4 *Lecture Hours*: 60 *Lab Hours*: 0
IT Domain Coverage: ITE-SPA 2-6

ITS 310: Cybersecurity Fundamentals

The course provides 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: ITS 301
Credits: 4 *Lecture Hours*: 60 *Lab Hours*: 0
IT Domain Coverage: ITE-CSP 2-7

ITS 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: ITS 300
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-SPA 7-10

ITS 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: CMPS 242
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-IMA 2-4

ITS 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: ITS 320, ITS 390
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-IST 2-6

ITS 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 is on the protocols used in the internet. A top-down approach is emphasized during the course starting from the application layer down to the data link layer.

Prerequisites: ITS 360
Credits: 4 *Lecture Hours*: 60 *Lab Hours*: 0
IT Domain Coverage: ITE-NET 2-7

ITS 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 explained using the concepts of process management, synchronization, deadlocks, job and process scheduling.

Prerequisites: CMPS 220, CMPS 242
Credits: 4 *Lecture Hours*: 60 *Lab Hours*: 0
IT Domain Coverage: ITE-PET 2-5

ITS 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: ITS 315
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-WMS 2-7

ITS 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: ITS 310
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-CSP 8-14

ITS 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: ITS 410
Credits: 3 *Lecture Hours*: 45 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 2-7

ITS 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: ITS 320
Credits: 3 *Lecture Hours*: 30 *Lab Hours*: 30
IT Domain Coverage: ITE-IMA 5-7

ITS 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: ITS 340, ITS 320
Credits: 1 *Lecture Hours*: 15 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 6-10

ITS 491: Practical Training

Training is an important aspect of the educational process. Students must 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.
Credits: 1 *Lecture Hours*: 0 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 8-11

ITS 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 focuses on topics 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: ITS 390, ITS 310, ITS 490
Credits: 2 *Lecture Hours*: 30 *Lab Hours*: 0
IT Domain Coverage: ITE-GPP 3,4,6-10

ITS 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: ITS 492
Credits: 4 *Lecture Hours*: 0 *Lab Hours*: 0
IT Domains Coverage: ITE-GPP 12

C.6 Typical IT Curriculum – China

Information Technology Program
Administered by a Computer Science Department in China

C.6.1 Program Goals and Features

The program aims to cultivate the advanced computer science and technical professionals who have solid background, widely scoped knowledge, independent creativity, and are with distinctive characteristics of the mobile internet.

C.6.2 Summary of Requirements

This program of study contains 26 required computer science (CMPC) courses (89 credits). Flexibility occurs by four computer science elective courses (12 credits), 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. This curriculum requires 48 courses, with credit hours distributed as follows.

Requirement Type	No. of Course	Courses	Credits
University Requirements	9	F101, 102, 502	7
		F201, 202, 103A	7
		F403, 301, 401	2.5
		Total Area Credits	**16.5**
Department Requirements (General)	6	F104A, 104B, 204A, 204B	16
		CMPC102	2
		F402	3
		Total Area Credits	**21**
Department Requirements (Math & Science)	7	F105A, CMPC104	6.5
		F207, 205	6
		F107, 206, 106	8
		Total Area Credits	**20.5**
Department Requirements (Filed Specific)	26	CMPC101, 103, 201, 202, CMPC203, 208, 206	25.5
		CMPC 209, 301, 331, 327	10.5
		CMPC 311, 312, 332, CMPC 314, 333, 711, 323	20
		CMPC 501, 601	5
		4 IT Electives Courses	12
		CMPC 401, 402	16
		Total Area Credits	**89**
Total Credits	**48**	*Total Credits*	**147**

C.6.3 Four-Year Model for China Curriculum

CMPC: Offered in a computing department

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
F101	Principles of Marxism	3	F502	Ideological and Political Theory and Social Practice	1
F102	Moral Cultivation and Legal Knowledge	3	F104B	College English (II)	4
F103A	Physical Education	1	F106	Lab of College Physics	2
F104A	College English (I)	4	F107	University Physics(I)	4
F105A	Calculus(I)	4.5	CMPC104	Intro. to Discrete Mathematics	2
CMPC101	Programming	4	CMPC103	Data Structure	4
CMPC102	Introduction to Computing	2	CMPC501	Comprehensive Course Design I for Computer Major	2
	Total Credits	**21.5**		*Total Credits*	**19**
Semester 3			**Semester 4**		
F204A	College English (III)	4	F202	A Concise History of Modern & Contemporary China	2
F201	Mao Zedong Thought & Theoretical System of Socialism with Characteristics	4	CMPC209	Principles and Experiments of Computer Networks	4
F205	Linear Algebra	3	F204B	College English (IV)	4
F206	University Physics(ＩＩ)	2	F207	Probability & Mathematical Statistics（A)	3
CMPC201	Computer System	5	CMPC206	Principles of Operating System	4
CMPC202	Object-Oriented Programming	3	CMPC208	Database System: Design & Development	3
CMPC203	Principles of Database System	2.5	CMPC601	Comprehensive Course Design II for Computer Major	3
	Total Credits	**23.5**		*Total Credits*	**23**
Semester 5			**Semester 6**		
F301	Physical Fitness Measurement (I)	0.5	CMPC327	IOS Mobile Application Development	3
CMPC301	Foundation of Software Engineering	2.5	CMPC314	Cross-platform Script Development Technology	3
CMPC311	Intelligent Terminal and Mobile Application Development	3	CMPC333	JAVA EE Architecture & Application Development	3
CMPC312	Technology and Application of the Internet of Things	3	CMPC323	Software Development Guidelines	2
CMPC331	Advanced JAVA Programming	3	ITC***	IT Elective 1	3
CMPC332	Programming Language Principle and Compiler	3	CMPC711	Mobile Internet Application Development Practice	3
	Total Credits	**15**		*Total Credits*	**17**
Semester 7			**Semester 8**		
F401	Physical Fitness Measurement(II)	1	F403	Current Trends & Policies	1
CMPC401	Graduation Practices	4	CMPC402	Graduation Thesis	12
ITC***	IT Elective 2	3	ITC***	IT Elective 4	3
ITC***	IT Elective 3	3			
F402	Basic Quality Practice	3			
	Total Credits	**14**		*Total Credits*	**14**

C.6.4 Mapping of Information Technology Curricular Framework to China Curriculum

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

Essential Domains / ***Courses***	**NET**	**WMS**	**IMA**	**SWF**	**PET**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
CMPC 101				2-3						
CMPC 102				1						
CMPC 103				5-6						
CMPC 501				4						
CMPC 201					4-5					
CMPC 202				4						
CMPC 203			1-4							
CMPC 206					1-4					
CMPC 208			5-7							
CMPC 209	1-5,7									
CMPC 601								1,9-10	1-2,4,6	
CMPC 301								1-3		8
CMPC 311		1-5		7			4-7			
CMPC 312	6									
CMPC 331		6		4						
CMPC 332										
CMPC 327		5,7		7			1-3,8			
CMPC 314						4-5				
CMPC 333										12
CMPC 711				7			2-4			
CMPC 323						1-2		5-6		9-10
CMPC 401										1-2
CMPC 402										7,11
Subdomains Covered	1-7	1-7	1-7	1-7	1-5	1-2, 4-5	1-8	1-3, 5-6, 9-10	1-2, 4,6	1-2, 7-12

C.6.5 China Curriculum – Course Summaries

CMPC 101: Programming
Overview of data types and expression; controlling structures (sequence, switch, loop); function; arrays; pointers; structures; file operations; basic debugging techniques; common algorithms.
Prerequisites: None
Credits: 4 *Lecture Hours*: 48 *Lab Hours*: 32
IT Domain Coverage: ITE-SWF 2-3

CMPC 102: Introduction to Computing
Discussion concerning specialty knowledge and courses; computing process and programming; data processing and information systems; mobile internet and applications; computer networks and security; societal and occupation issues.
Prerequisites: None
Credits: 2 *Lecture Hours*: 32 *Lab Hours*: 0
IT Domain Coverage: ITE-SWF 1

CMPC 103: Data Structures
Topics include basic concepts of data structures; evaluating methods for algorithms; logical structures of data (including linear list, stack, queue, tree, graph, etc.); storage structures of data (including sequence storage and link storage); materializing methods on types of basic operations; common methods of sorting algorithms and searching algorithms.
Prerequisites: CMPC 101
Credits: 4 *Lecture Hours*: 48 *Lab Hours*: 32
IT Domain Coverage: ITE-SWF 5-6

CMPC 501: Comprehensive Course Design for Computer Majors
Data types and expression; controlling structures (sequence, switch, loop); functions; arrays; pointers; structures; file operations; basic debugging; common algorithms.
Prerequisites: CMPC 101, CMPC 103
Credits: 4 *Lecture Hours*: 48 *Lab Hours*: 32
IT Domain Coverage: ITE-SWF 4

CMPC 201: Computer Systems
Topics include computer system introduction; machine-level programs; program execution mechanism; storage systems and accessing; executable code generation, exception and interruption, I/O and file operations.
Prerequisites: CMPC 101
Credits: 5 *Lecture Hours*: 64 *Lab Hours*: 32
IT Domain Coverage: ITE-PET 4-5

CMPC 202: Object-Oriented Programming
Introduction to computers, programs, and Java; elementary programming; objects and classes; strings and text I/O; thinking in objects; inheritance and polymorphism; exception handling; abstract classes and interfaces; binary I/O; generics, Java collection framework.
Prerequisites: CMPC 101
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-SWF 4

CMPC 203: Principles of Database Systems
Overview of database system management; data models; organization of database systems; relational-databases; relational algebra and relational calculations; SQL language; query optimization.
Prerequisites: CMPC 101
Credits: 2.5 *Lecture Hours*: 32 *Lab Hours*: 16
IT Domain Coverage: ITE-IMA 1-4

CMPC 206: Principles of Operating Systems
Role and purpose of operating systems; process and thread management; process synchronization and concurrency; storage management: memory management and virtual memory; process scheduling; /O device management and file management.
Prerequisites: CMPC 101, CMPC 103
Credits: 4 *Lecture Hours*: 48 *Lab Hours*: 32
IT Domain Coverage: ITE-PET 1-4

CMPC 208: Databases Systems: Design and Development
Approaches to database application development; database application analysis and design methodology; development of database applications with typical tools such as: MS SQL Server, JDBC, and Eclipse.
Prerequisites: CMPC 203
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-IMA 5-7

CMPC 209: Principles and Experiments of Computer Networks

Introduction to computer networks; network architectures and network protocols; physical layer and data link layer; MAC sublayer; network layer; transport layer; application layer; network security.
Prerequisites: None
Credits: 4 *Lecture Hours*: 48 *Lab Hours*: 32
IT Domain Coverage: ITE-NET 1-5, 7

CMPC 601: Comprehensive Course Design II for Computer Majors

Database fault diagnosis and analysis; Oracle Listener configuration and management; Oracle console management; SCN and Checkpoint; database startup and shutdown; database space management and monitoring; Oracle performance optimization; SGA performance optimization; database physical backup and recovery; physical data guard configuration and management; comprehensive practical projects.
Prerequisites: CMPC 203
Credits: 3 *Lecture Hours*: 0 *Lab Hours*: 96
IT Domain Coverage: ITE-SPA 1, 9-10, ITE-CSP 1-2, 4, 6

CMPC 301: Foundations of Software Engineering

Software processes; specification and requirement analysis; software analysis and design; programming techniques and tools; software verification and validation; software metrics.
Prerequisites: CMPC 101, CMPC 102, CMPC 302
Credits: 2.5 *Lecture Hours*: 32 *Lab Hours*: 16
IT Domain Coverage: ITE-SPA 1-3, ITE-GPP 8

CMPC 311: Intelligent Terminal and Mobile Application Development

Mobile internet application basic and features; Android application basics; UI design; data storage; networking application design; advanced application design (sensors, camera, GPS, Audio etc.); graphics and games; web-based hybrid application design.
Prerequisites: CMPC 302
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-WMS 1-5, ITE-SWF 7, ITE-UXD 4-7

CMPC 312: Technology and Application of the Internet of Things

Network structure of IoT; software and hardware platform and system composition of IoT; cloud computing; node sensing and identification technologies including the basic principle of radio frequency identification; RFID system and its typical application; sensor and detection technologies.
Prerequisites: CMPC 201, CMPC 203, CMPC 206, CMPC 209
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-NET 6

CMPC 331: Advanced Java Programming

Main character and basic knowledge of Java and XML; character and method of object-oriented, stream disposal of Java; multi-thread programming; GUI programming.
Prerequisites: None
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-WMS 6, ITE-SWF 4

CMPC 332: Programming Language Principles and Compilers

Formal aspects of syntax and semantics; naming, scoping and binding; scanning, parsing; semantic analysis; control flow, subroutines type systems, data abstraction and storage management; imperative, functional and object-oriented programming paradigms, programming environments and tools.
Prerequisites: None
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: None

CMPC 327: iOS Mobile Application Development

Overview of iOS platform application programming; introduction to iOS architectures; objective-C programming language; view and view controller; touch event handling; usage of interface controls; use of development tools; data persistence, multimedia, networking, game development.
Prerequisites: CMPC 101, CMPC 201
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-WMS 5, 7, ITE-SWF 7, ITE-UXD 1-3, 8

CMPC 314: Cross-platform Script Development Technology

JavaScript basics; JavaScript design patterns; script modularization; script deployment and packaging; JavaScript frontend design; JavaScript backend design; backbone.js; node.js; solution architectures; cross-platform applications.
Prerequisites: CMPC 101, CMPC 103, CMPC 302,
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-IST 4-5

CMPC 333: Java EE Architecture and Application Development
Basic concepts of J2EE; programming techniques; server level techniques (Enterprise JavaBean); client level techniques, network level techniques (Servlet / JSP); EJB query language, data transaction and security, packing, deploying.
Prerequisites: None
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-GRR 12

CMPC 711: Mobile Internet Application Development Practice
Responsive UI designs; web app design; hybrid app design; interact with backend service; backend service design; requirement analyze and mobile internet context based design; app tools; integration and deploy.
Prerequisites: CMPC 202, CMPC 311, CMPC 314
Credits: 3 *Lecture Hours*: 32 *Lab Hours*: 32
IT Domain Coverage: ITE-SWF 7, ITE-UXD 2-4

CMPC 323: Software Development Guidelines
Risk analysis of software development; schedule management; workload analysis; requirement analysis; code specifications; test specifications; quality assurance; communication management.
Prerequisites: CMPC 301
Credits: 2 *Lecture Hours*: 32 *Lab Hours*: 0
IT Domain Coverage: ITE-IST 1-2, ITE-SPA 5-6, ITE-GPP 9-10,

CMPC 401: Graduation Practices
Participation in the development and research of a real project; student in charge of making a relatively independent sub-function module by using gained knowledge and mastered tools; execution may be out of school, to take part in the real project offered by other organizations or in school, to take part in a teacher’s research projects.
Prerequisites: Permission of the department
Credits: 4 *Lecture Hours*: 0 *Lab Hours*: 128
IT Domain Coverage: ITE-GPP 1-2

CMPC 402: Graduation Thesis
Students do literature translation, literature survey, opening report, system design and development, thesis writing and defending; students acquire scientific research ability, system design and development ability, develop a basis for future work.
Prerequisites: Permission of the department
Credits: 12 *Lecture Hours*: 0 *Lab Hours*: 384
IT Domain Coverage: ITE-GPP 7,11

Appendix D: Information Technology in Other Contexts

This appendix to this report contains several sample curricula that illustrate possible implementation of the information technology curriculum in contexts other than a traditional four-year information technology program. Because information technology is relatively new as a discipline, institutions sometimes offer IT related baccalaureate degree programs within a previously established discipline. In this context, the IT degree program exists within an already established information systems program or within an established computer science program. The information technology courses may occur as computer science or even information systems courses. Another context is that of a three-year implementation of the degree as is common in Europe and Australasia. Some institutions may even offer a mechanism for the graduate of a two-year program to return and complete a four-year degree within a "2+2" context.

The following table summarizes the sample curricula in this appendix. It serves as a guide for identifying sample curricula relevant to these difference contexts. None of these samples is prescriptive.

Type of the Program	Country/Region	Appendix Section
Bachelor of Computer Information Systems	Canada	D.2
Bachelor of Arts in Applied Computer Science	United States	D.3
Bachelor of Business Administration in Information Security and Assurance	United States	D.4
Three-year Baccalaureate Program in Information Technology	Europe	D.5
2+2 Baccalaureate Degree Program	United States, Canada, and other places	D.6
Design for All – A major in an ICT Curriculum	Spain	D.7
Three Years' Bachelor of Information and Communications Technology Example	South Africa	D.8
Bachelor of Information Technology	Australasia	D.9
Bachelor of Information Technology	Latin America	D.10

D.1 Format and Conventions

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

1. A statement of goals or features for the program
2. A summary of degree requirements 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 IT courses in the curriculum

D.1.1 Course Time 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 MATH 100 is a course in a curriculum commonly taught in the first year (at the first-year level). Likewise, PHYS 201 is a course commonly taught in the second year (at the sophomore level); IT 305 is a course commonly taught in the third year (at the junior level); and course IT 405 is usually a fourth-year course.

To provide ease of comparison, all curricula implementations appear as a set of courses designed for a system in which a semester provides 15 weeks of lecture and laboratory including the equivalent of one week for examinations, vacations, and reading periods. 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 some credits, according to the number and types of formal activities within a given week, determined as follows.

- Lecture hours: presentation of material in a classroom setting
    - 1 credit = One, 1-hour lecture per week for 15 weeks (including exams)
- Laboratory hours: formal experimentation in a laboratory setting
    - 1 credit = One, 3-hour or 2-hour laboratory session per week for 15 weeks (including exams)

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 lectures per week for 15 weeks = 45 lecture hours (including exams)
- *1-credit laboratory course*:
  Either one 2-hour laboratory session per week for 15 weeks = 30 lab hours (including exams)
  or one 3-hour laboratory session per week for 15 weeks = 45 lab hours (including exams)
- *3-credit course with two lectures and one lab session each week*:
  2 lecture hours per week for 15 weeks = 30 lecture hours (including exams)
  One 2-hour or 3-hour lab per week for 15 weeks = 30 or 45 lab hours (including exams)
- *3-credit project design course*:
  1 classroom meeting per week for 15 weeks = 15 lecture hours (including exams)
  2, 2-hour or 3-hour lab per week for 15 weeks = 60 or 90 lab hours (including exams)

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

Each sample curriculum contains a table that maps the information technology curricular framework to the sample blended curriculum. The table heading contains the names of the essential domains. 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 perspectives, but from two different points of view.

The required courses in a sample blended curriculum may not cover all the essential and the supplementary domains. The key to fitting the information technology curriculum into the larger program lies in what to do with the free technical electives and “other” curricular space.

D.2 Canadian Example

Bachelor of Computer Information Systems, Administered by the Dep. of Mathematics and Computing and jointly offered with the School of Business, Mount Royal University, Calgary, Alberta, Canada
http://www.mtroyal.ca/ProgramsCourses/FacultiesSchoolsCentres/ScienceTechnology/Programs/BachelorofComputerInformationSystems/CurriculumCourses/index.htm

D.2.1 Program Goals and Features

This degree program develops graduates that are familiar with computer information technology and in the fundamentals of business. This is an example of IT degree such as one offered from a business school or college.

D.2.2 Summary of Requirements

The program's major requirement of 24 courses consists of 15 to 17 computer science courses and 7 to 9 business courses. This allows the student to bias his or her program toward computer science or business depending on interest. The general education requirement of 12 courses includes a required mathematics course, a required business communication course, and a required information technology ethics course. The student can select an additional 4 courses from any category for a total of 40 courses. There is also a requirement for one 4-month non-credit work experience term.

This program provides more emphasis on programming and systems analysis than the IT model. In addition, curricular space should cover the 7 to 9 business courses as well as four "free" student electives. As a result, some of the essential domains occur with optional courses. This means that most students will not have taken all the essential domain content.

D.2.3 BCIS - Suggested Schedule 4 Years (Five courses per semester)

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
COMP 1501	Programming I: Intro to Problem Solving	3	COMP 1502	Programming II: Object Oriented Programming	3
	Core Business	3	COMP 2511	Web I: Client Dev.	3
GNED 11xx	General Education – Tier 1	3		Core Business	3
GNED 14xx	General Education – Tier 1	3	MGMT 3210	Business Communication	3
GNED 1xxx	General Education – Tier 1	3	MATH 1505	Puzzling Adventures in Mathematics	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 3			**Semester 4**		
COMP 2503	Programming III: Data Structures	3	COMP 2531	Computer Architecture and Operating Systems	3
COMP 2521	Database I: Data Modelling and Query Languages	3	COMP 2541	Systems Analysis	3
	Core Business	3		Core Business	3
GNED 1xxx	General Education – Tier 1 – cluster 2 or 3	3	GNED 2xxx	General Education – Tier 2	3
GNED 2xxx	General Education – Tier 2	3		Student Elective	3
COOP 0001	Work Experience Preparation	0	COMP 3591	Mandatory Work Experience	0
	Total Credits	**15**		*Total Credits*	**15**
Semester 5			**Semester 6**		
COMP 3512	Web II: Web Application Development	3	COMP 3533	Networking and Security	3
COMP 3532	System Administration and Maintenance	3	COMP 3309	Information Technology and Society	3
	Senior Business Option	3		Senior Comp or Business option	3
	Senior Business Option	3		Senior Comp option	3
GNED 2xxx	General Education – Tier 2	3		Student elective	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 7			**Semester 8**		
COMP 4543	Project Management and Quality Assurance	3		Senior Comp option	3
	Senior Comp option	3		Senior Comp option	3
	Senior Comp or business option	3		Senior Business option	3
GNED	General Education – Tier 3	3		Student Elective	3
GNED	General Education – Tier 3	3		Student Elective	3
	Total Credits	**15**		*Total Credits*	**15**
Senior Computer Option Courses					
COMP 3012	Robotics	3			
COMP 3504	Programming IV: Software Engineering	3			
COMP 3553	Human Computer Interaction	3			
COMP 4513	Web III: Advanced Web Development	3			
COMP 4522	Database-II: Advanced Databases	3			
COMP 4535	Computer Security	3			
COMP 4545	Information Systems Organization	3			
COMP 4555	Games Development	3			

D.2.4 Mapping of BCIS to subdomains of Essential Curricular Framework

Essential Domains / ***Courses***	**NET**	**WMS**	**IMA**	**SWF**	**PFT**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
Core										
COMP 1501				1-4						
COMP 1502				2-4			3			
COMP 2503				1-6						
COMP 2511		1-3					3			
COMP 2521			1-4							
COMP 2531					1-5					
COMP 2541								1-4		4,9,10, 12
COMP 3309		7								1
COMP 3512		4-6				1-4				
COMP 3532								7-10		
COMP 3533	1-7									
COMP 4543								4-6		8,10
Options										
COMP 3012		5		4,7	5			5,6		
COMP 3504		5-7		7		3-4	3			
COMP 3553							1-8			
COMP 4513		4-7				2-6				
COMP 4522			5-7							
COMP 4535									1-6, 8,13,14	
COMP 4545										1-4, 11,12
COMP 4555		5-7		7		3,4	3			
Subdomains Covered	1-7	1-7	1-7	1-7	1-5	1-6	1-8	1-10	1-6, 8,13,14	1-4, 8-12

D.3 Applied Computer Science Example

Bachelor of Arts in Applied Computer Science, Administered by the Department of Computer Science, College of Computing and Software Engineering, Kennesaw State University, Georgia, USA
http://ccse.kennesaw.edu/cs/programs/baacs.php

D.3.1 Program Goals and Features

Applied Computer Science is less formal and mathematical and instead focuses more on applied computing. The BA targets emerging fields within computer science including those spanning other disciplines.

D.3.2 Summary of Requirements

The degree requires 9 credit hours of math courses including calculus I, a sequence of two lab sciences, foreign language, two traditional computer science courses, two courses from information systems, and eight applied computer science courses in web development, social media, databases, game design, Linux OS, mobile computing, data warehousing, cloud computing, data mining, and robotics. The BA can integrate with other disciplines through the required concentration. As a result, there is no coverage for routing and switching (NET3-5), system acquisition and sourcing (SIA4), and some of the essential domains occur within optional courses. This means that most students will not have taken all the essential domain courses.

D.3.3 BAACS - Suggested Schedule 4 Years (Five courses per semester)

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
ENGL 1101	Composition I	3	ENGL 1102	Composition I	3
MATH 1113	Precalculus	4	MATH 1190	Calculus I	4
IS 2200	Information Systems and Communication	3	FL 1002 or COM 1100	Foreign language or Human Communications	3
KSU 1XXX	First-year or transfer seminar	0-3	Area E course	Social Sciences	3
ACST 2301	Problem-Solving and Digital Game Design	3	CS 1301	Programming Principles I	4
	Total Credits	**13-15**		*Total Credits*	**17**
Semester 3			**Semester 4**		
IS 3260	Web Development I	3	MATH 1107	Introduction to Statistics	3
ACST 3150	Programming with .NET Framework	4	CS 3410	Introduction to Database Systems	3
Area D	lab science	4	Area D	lab science	4
FL 2001	Foreign language	3	FL 2002		3
Area C-2	Arts and Culture of the World	3	ACST 3540	Social Media & Global Computing	3
	Total Credits	**17**		*Total Credits*	**16**
Semester 5			**Semester 6**		
Area E	Social Sciences	3	ECON 1000	Contemporary Economic Issues	2
Concentration	Course from concentration	3	Concentration	Course from concentration	3
Area C-1	Literature of the World	3	Concentration	Course from concentration	3
ACST 3510	Computer Architecture and Robotics	3	ACST 3530	Linux Operating Systems and Networking	3
Area E	Social Sciences	3	ACST 3330	Data Structures and Database Applications	3
	Total Credits	**15**		*Total Credits*	**14**
Semester 7			**Semester 8**		
Concentration or Elect	Course from required concentration or major elective	3	Free Elective		3
Concentration	Course from required concentration	3	Concentration	Course from required concentration	3
Area E	Social Sciences	3	ACST 4620	Computing Security	3
ACST 3710	Digital Game Design	3	ACST xxxx	Major Elective	3
ACST XXXX	Major Elective	3	CS 4850	Senior Project	3
	Total Credits	**15**		*Total Credits*	**15**
Option Courses					
ACST 3720	Process and Systems Modeling	3			
ACST 4320	Data Warehousing and Mining	3			
ACST 4550	Mobile Computing with Android	3			
ACST 4570	Cloud Computing	3			

D.3.4 Mapping of BAACS to subdomains of Essential Curricular Framework

Essential Domains / ***Courses***	**NET**	**WMS**	**IMA**	**SWF**	**PFT**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
Core										
ACST 2301				1,3			1			
ACST 3150				3,4,7			2,3			
ACST 3330			4	5,6		2		2,3,5		
ACST 3510					1-5	3		5,6		
ACST 3530	1,2,6,7					4,5		7-10		
ACST 3540		7				3,6	4,5		7,12	7,9,10
ACST 3710		4,5		2,4,7		3				
ACST 4620		6							1-6,8-11,13,14	
CS 1301				1-4						
CS 3410			1-5,7							
CS 4850										8,11
IS 2200						1			1	1-6,9,10,12
IS 3260		1-3								
Options										
ACST 3720			3				4-8	1,5,6		
ACST 4320			6							
ACST 4550		1,4,5		4,7						
ACST 4570						3,4				
Subdomains Covered	1,2,6,7	1-7	1-7	1-7	1-5	1-6	1-8	1-3, 5-10	1-14	1-12

D.4 Bachelor of Business Administration in Information Security and Assurance Example

Bachelor of Business Administration in Information Security and Assurance, Administered by the Department of Information Systems, College of Business, Kennesaw State University, Georgia, USA
http://coles.kennesaw.edu/programs/undergraduate/information-security-assurance.php

D.4.1 Program Goals and Features

The purpose of the Bachelor of Business Administration in Information Security and Assurance (BBA-ISA) program is to create technologically proficient, business-savvy information security professionals capable of applying policy, education, and technology solutions to protect information assets from all aspects of threats, and to manage the risks associated with modern information usage. Information security is the protection of the confidentiality, integrity, and availability of information while in transmission, storage or processing, through the application of policy, technology, and education and awareness. Information assurance concerns information operations that protect and defend information and information systems by ensuring availability, integrity, authentication, confidentiality, and nonrepudiation. This program spans both areas in its approach to the protection of information in the organization.

D.4.2 Summary of Requirements

The degree requires several business and marketing courses, six credit hours of math, including Elementary Applied Calculus or Calculus I, a sequence of two lab sciences, two information systems courses, and 10 information security and assurance courses in operating systems, client/server security, networking and business continuity. This program provides more emphasis on cybersecurity than the IT model. As a result, some of the essential domains are only partially covered. All option courses cover more information security and assurance content. This means that most students, unless they take IT/IS/CS electives will not have taken all the Integrated Systems Technology, User Experience Design and Web and Mobile Systems essential domains content.

D.4.3 BBA-ISA - Suggested Schedule 4 Years (Five courses per semester)

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
ENGL 1101	Composition I	3	ENGL 1102	Composition I	3
MATH 1111, 1112, or 1113	College Algebra or Trigonometry/Precalculus	3	MATH 1160, 1190, or 2202	Elementary Applied Calculus/Calc I or II	3-4
ECON 1000	Contemporary Economic Issues	2	ACCT 2100	Intro to Financial Accounting	3
Area D2–	Science course with lab	4	ECON 2100	Principles of Microeconomics	3
KSU 1xxx	First Year seminar	0-3	Area D2	Science Process – Group 2 course	3
	Total Credits	**12-15**		*Total Credits*	**15-16**
Semester 3			**Semester 4**		
ACCT 2200	Introduction to Managerial Accounting	3	BLAW 2200	Legal and Ethical Environment of Business	3
ECON 2200	Principles of Macroeconomics	3	Area C1	Literature of the World	3
ECON 2300	Business Statistics	3	Area C2	Arts & Culture of the World	3
IS 2200	Information Systems and Communication	3	HIST 1100, 1111, or 1112	World History	3
BUSA 2150	Discovering My Major and Career	0	POLS 1101	American Government	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 5			**Semester 6**		
ISA 3100	Information Systems Management	3	ISA 3200	Network Security	3
ISA 3010	Security Script Programming	3	ISA 3300	Management of Information Security in a Global Environment	3
ISA 3210	Client Systems Security	3	ISA 4xxx	Major Field Elective	3
BUSA 3150	Developing My Career Essentials	0	FIN 3100	Principles of Finance	3
ECON 3300	Applied Statistical and Optimization Models	3	MGT 3100	Management and Behavioral Sciences	3
IS 3100	Information Systems Management		WELL 1000	Foundations for Healthy Living	3
	Total Credits	**15**		*Total Credits*	**18**
Semester 7			**Semester 8**		
ISA 4200	Perimeter Defense	3	ISA 4820	Information Security and Assurance Programs and Strategies	3
ISA 4220	Server Systems Security	3	MGT 4199	Strategic Management	3
BUSA 4150	Driving My Success	0	ISA 4xxx	Major Field Elective	3
HIST 2111 or 2112	US History	3		Business Elective	3
MGT 3200	Operations Management	3		Business Elective	3
MKTG 3100	Principles of Marketing	3		Non-Business Elective	3
	Total Credits	**15**		*Total Credits*	**18**

D.4.4 Mapping of BBA-ISA to subdomains of Essential Curricular Framework

Essential Domains / ***Courses***	**NET**	**WMS**	**IMA**	**SWF**	**PFT**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
Core										
BLAW 2200		7								5-7
BUSA 2150										2,8,11,12
IS 2200						1			1	1-6,9,10,12
IS 3100			1-2					1-6		
ISA 3010				1-7		5-6				
ISA 3100									1-10	
ISA 3200	1-7									
ISA 3210		6			1-4			7-11		
ISA 3300									12-14	3-5
ISA 4200									3-4,11-14	
ISA 4220								7-11		3-5,13
ISA 4820										4,6,8,9,10
MGT 3100										5-6
MGT 3200							1,2,7			
MGT 4199										8-10
Subdomains Covered	1-7	6,7	1-2	1-7	1-4	1, 5-6	1,2,7	1-11	1-14	1-11

D.5 Three-year Program Baccalaureate Example

(Based on European and similar regions such as New Zealand)

Bachelor of Information Technology, global example, mainly based on exemplary actual curricula administered by Geneva IT Institute is an Information Technology and the Otago Polytechnic New Zealand.

D.5.1 Program Goals and Features

This degree program develops graduates that study information technology (IT) for a variety of reasons to be a computing professional, to use IT to be a better scientist, or to empower themselves to better understand the technology behind many of today's careers. Increasingly, employers see an IT qualification as a sign of academic well roundedness. IT drives innovations such as the human genome project, vaccine research, environmental modelling. Key IT areas include cyber security, mobile computing, cloud computing, and data analytics. Independent job market surveys show that demand for graduates is escalating, along with salaries and industry has concerns about a shortage of talent.

A major objective is to respond to industry and market requirements by giving more importance to practical considerations. Every industry, organization and business in the world relies on computer technology in one way or another and the right qualification will create numerous employment opportunities for you, both here and overseas. There are currently far more IT jobs than there are graduates and employers are desperate for individuals with a solid understanding of the industry and a willingness to continue developing new skills. Graduates could become a web developer, systems administrator, software developer, programmer, business analyst, database administrator or computing services manager, amongst many others!

D.5.2 Summary of Requirements

Skills required for this degree program include good communication skills, a facility with technical skills, as well as planning, organizational and problem-solving skills. All students receive individual assessments to ensure they meet degree level entry requirements and must have achieved the equivalent of the required level of mathematics. If English is not a student’s first language, the applicant must demonstrate English language skills equivalent to an IELTS overall band score (academic) of 6.0, with no band score less than 5.5. Many schools in Europe and all in Australia and in New Zealand offer programs in English.

IT courses or modules are typically worth the equivalent of three or four hours contact time per week. A full-time program will usually consist of four or five modules per semester or ten modules per year. During an average week, students generally undertake 15 to 16 hours of directed learning and an additional 15-20 hours of self-directed study completing assignments and reading.

The programs’ major requirements consist of about 30 modules or courses of which a maximum of 10 can be electives from a related domain such as visualization, computer graphics, data analysis, physical computing, and interaction design studio. There is a final practical project of four to six months, mostly in teams of about four students.

Each module contains individual or supervised training periods. The final project is 100% practice. Exams can be taken a second time in case of failure.

D.5.3 General example: Typical Schedule 3 Years (Ten courses per year over six semesters)

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
COMP 1011	Professional Practice	3	COMP 1013	TCP/IP and Networking	3
COMP 1021	MS-Office level 1 or ECDL	3	COMP 1023	VB.NET level 1	3
COMP 1022	Intro. Programming	3	COMP 1032	Task Analysis and Web design	3
COMP 1031	HTML Programming	3	COMP 10**	IT Elective	3
COMP 1033	Cascading Style Sheets (CSS)	3	COMP 10**	IT Elective	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 3			**Semester 4**		
COMP 2011	MS Exchange Server	3	COMP 2023	Java level 1	3
COMP 2013	Routing & Switching	3	COMP 2012	Linux	3
COMP 2021	MS-Office level 2	3	COMP 2031	Joomla	3
COMP 2022	C++ level 1	3	COMP 2034	Multimedia and User Interface	3
COMP 2033	Web Server	3	COMP 20**	IT Elective	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 5			**Semester 6**		
COMP 3011	Telecoms	3	COMP 3013	VMware	3
COMP 3012	Systems Security	3	COMP 3021	SQL/MySQL	3
COMP 3022	VB.NET level 2	3	COMP 3032	PHP Programming	3
COMP 3031	JavaScript	3	COMP 30**	IT Elective	3
COMP 3023 or COMP 3024	C++ level 2 Java level 2	3	COMP 3100	Final Project	3
	Total Credits	**15**		*Total Credits*	**15**

D.5.4 Mapping of this curriculum to subdomains of Essential Curricular Framework

Essential Domains / Courses	NET	WMS	IMA	SWF	PFT	IST	UXD	SPA	CSP	GPP
COMP 1011							1,8			1-12
COMP 1013	1-7									
COMP 1021				1-2						
COMP 1022				1-4						
COMP 1023					1-4					
COMP 1031				1-4						
COMP 1032		1-4					2,3,4,7			
COMP 1033								1-2		
COMP 2011						1-6			1-3	
COMP 2012					1-5					
COMP 2013	4-7					1-3				
COMP 2021				1-3						
COMP 2022				1-7						
COMP 2023				1-7						
COMP 2031			1-3					1-3		
COMP 2033		1-7								
COMP 2034		3-5					2,3,5,6			
COMP 3011	6-7									
COMP 3012							1,8		1-14	
COMP 3013					3-5					
COMP 3021			4-7							
COMP 3022					1-5					
COMP 3023				4-7						
COMP 3024				4-7						
COMP 3031				2-4						
COMP 3032				2-4						
COMP 3100										
Subdomains Covered	1-7	1-7	1-7	1-7	1-5	1-6	1-8	1-3	1-14	1-12

D.6 2+2 Baccalaureate Degree Program Example

In some jurisdictions in North America, institutions have constructed programs to allow a student who has graduated from a two-year program (Associate Degree in the United States, Diploma in Canada) to transfer courses they completed in a two-year program into a four-year degree program. Ideally, students would be able to complete the four-year degree in two extra years. At first glance, this may sound trivial. Student have already completed two years at institution A so all they need to do is to take the third and fourth year at institution B for the degree. However, it turns out not to be that simple.

The two-year program (institution A) usually has a few courses that satisfy as third or even possibly fourth year. Curricular space for these advanced courses occurs by some combination of the following: offering fewer general education courses, reducing mathematics, or offering computer courses with decreased emphasis on fundamental topics in favor of applied topics. The result is that the student has not taken all the courses in the first and second year of the degree and some of the computer courses taken do not map well to the degree equivalents. To overcome these problems, accommodations must occur at institution B. The student may have to take extra courses to make up for the deficits thus leading to longer program. Sometimes, the degree requirements may require modification to allow for timely graduation.

The example below shows how the courses in a two-year program can map to a four-year degree.

D.6.1 Program Goals and Features

This degree program offers a university baccalaureate degree in information technology with a broad foundation and electives that allow specialization in any one of several areas within IT. The requirements for the associate degree program offered by a community college, representing the first two years of the bachelor's degree, align tightly with the university program.

D.6.2 Summary of Requirements

The example below shows the core requirements for the degree. Students take the first two years of courses at a community college, and the credits transfer to the university where the student competes the degree. Along the way, the student earns an associate degree from the community college. After completing the next two years at the university, students then earn a bachelor's degree. There are few electives in the first two years of the program. In the next two years, the student can choose a focus area for the electives.

D.6.3 General example: Typical 2+2 Schedule (Four semesters at associate degree/diploma level, four semesters at baccalaureate level)

Students take the first four semesters at a two-year school, such as a community or technical college, often resulting in an associate degree.

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
MTH 111	College Algebra	3	EC 201	Principles of Economics	3
COMM 111	Public Speaking	3	CIS 278	Data Communications Concepts	3
WR 121	English Composition	3	CIS 133	Intro to Programming C#.NET	3
CIS 145	Micro Computer Hardware	3	BA 206	Management Fundamentals	3
SC xxx	Laboratory Science Elective	3	WR 227	Technical / Professional Writing	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 3			**Semester 4**		
CIS 275	Relational Databases & SQL	3	CIS 288	Microsoft Network Administration	3
CIS 244	Systems Analysis	3	PSY 201	Intro to Psychology	3
CIS 233	Programming C#.NET II	3	COMM 215	Small Group Communication	3
BA 211	Principles of Accounting	3	CIS 245	Project Management	3
MTH 244	Statistics	3	ELEC	Elective	3
	Total Credits	**15**		*Total Credits*	**15**

In an ideal situation, all credits transfer from the two-year institution (institution A) to the four-year institution (institution B) and students enter with "junior" status. The remaining two years of courses, semesters 5-8, occur at the university as the second two years in a four-year program.

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 5			**Semester 6**		
ACC 325	Finance	3	BUS 457	Business Research Methods	3
BUS 356	Business Presentations	3	HUM xxx	Humanities Elective	3
WRI 350	Documentation Development	3	ELEC	Focused Sequence Elective	3
BUS 226	Business Law	3	ELEC	Focused Sequence Elective	3
ELEC	Focused Sequence Elective	3	ELEC	Focused Sequence Elective	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 7			**Semester 8**		
MGT 461	Lean/Six Sigma Management	3	MIS 498	Senior Project	3
MIS 496	Senior Project Management	3	BUS 478	Strategic Management	3
PSY 347	Organizational Behavior	3	PHL 342	Business Ethics	3
ELEC	Focused Sequence Elective	3	ELEC	Focused Sequence Elective	3
ELEC	Elective	3	ELEC	Focused Sequence Elective	3
	Total Credits	**15**		*Total Credits*	**15**

D.6.4 Mapping of this curriculum to subdomains of Essential Curricular Framework

The table below shows how the IT courses in the *first two years*, map to content in IT2017.

Essential Domains / ***Courses***	**NET**	**WMS**	**IMA**	**SWF**	**PFT**	**IST**	**UXD**	**SPA**	**CSP**	**GPP**
First Two Years										
CIS 145					1-4			1-3		
CIS 278	1-7									
CIS 133				1-4						
CIS 275			1-7							
CIS 244								1-6		8-10, 12
CIS 233		1-2		1-7		1-2	1-3			
CIS 288	6-7					5			1-3, 8, 12-14	
CIS 245										1-4, 6, 8-12
Subdomains Covered	1-7	1-2	1-7	1-7	1-4	1-2, 5	1-3	1-6	1-3, 8, 12-14	1-4, 6, 8-12

D.7 Design for All – A major in an ICT Curriculum

(Based on a Spanish major in a Computers and Telecommunications curriculum proposal)

D.7.1 Program Goals and Features

The main objective of this curriculum example is to allow Spanish ITC professionals acquire skills and knowledge (competences) applicable to the principles of "Universal Accessibility" and "Design for All" (*D4All*) in their everyday professional work. These competences are especially relevant whenever the potential users are people with special needs (senior citizens, people with disabilities, etc.).

The primary source for this example is from a "Major in a bachelor on a Computers and Telecomunnication Curricula" designed by Abascal and others for the Spanish Fundación ONCE and the Coordinadora del Diseño para Todos [Aba1]. Therefore, this curriculum teaches the design of ICT products and services in such a way that all people can use them. This includes future generations, regardless of age, gender, abilities, cultural background or the supporting technology which they require. It provides equal opportunities that enable access, use and understanding of any part of the communication environment with as great a degree of independence as possible. Hence, it applies the concept of *D4All.*

D.7.2 Summary of Requirements

This example presents specific courses that focus on "Universal Accessibility" and *D4All* into existing degree programs. Since this involves the European model, the Spanish example would require about four years to complete. That is, three years for the European plan of study plus an additional year to acquire the specialized baccalaureate degree.

The specifics of this additional component of the curriculum are arranged into thematic (compulsory and elective) sets of modules.

(a) The first three modules could occur within a course or grouping on "*D4All* and User-focused Evaluation"
(b) The three following modules could occur within another grouping on "Interfaces, Supporting Technologies and Web Applications"
(c) The last four modules form another grouping on "Advanced Knowledge on *D4All* and its use".

The above arrangement is suggestive of the sequence in which students study the sets; the sequence of modules in each set is a recommendation for the order suggested in the following section (D.7.3).

These teaching modules cover the topics of different size and complexity. The size of the modules is either 1 or 2 ECTS that follows the European Credit Transfer and Accumulation System (ECTS) framework established by the European Commission. The equivalence of 1 ECTS in the European model represents 150 student hours, split into 30 hours of theory sessions, 30 hours of practical or laboratory work, and 90 hours of individual personal study. Additionally, the modules partition into two types: compulsory modules that add up to 12 ECTS credits in total and elective modules added to a total of 6 ECTS credits maximum. The example proposed represents general recommendations such as the *European Qualifications Framework for Lifelong Learning* (EQF), *European Credit System for Vocational Education and Training* (ECVET), and similar recommendations in the *European Community Education and Training Directory*, as well as any related Spanish legislation.

D.7.3 Suggested Schedule of the modules, as taught within a Bachelor curriculum of 3-4 years

Set (a): *D4All* and User-focused Evaluation

Module	Title	Type	Credits	Objectives
1	*Design for all (D4All)* and target user groups	C	2	• demographics, user preferences and needs, benefits of *D4All*. • diversity of target groups; principles of *D4All* and user participation.
2	User-Centered Design	C	2	• User-Centered Design process principles and methods, including D4All • methods that support User-Centered Design and D4All process.
3	Evaluation of systems by users	C	2	• evaluation of user interfaces in terms of D4All (usability and accessibility) • methods for evaluating interfaces, automatically, by experts and by users.

Set (b). Interfaces, Supporting Technologies and Web Applications

Module	Title	Type	Credits	Objectives
4	User interfaces	C	2	• design of interfaces for broad spectrum of users and usage situations, including new user paradigms. • state of the art, innovative user interface design methods and D4All.
5	Assistive Technologies	C	2	• accessibility barriers for AT and D4All. • appropriate AT in specific environments for people with concrete needs. • in-depth understanding of the interoperability between AT and ICTs.
6	Web applications	C	2	• principles and methods for building Web applications for All • accessible and usable Web application design methods and guidelines.

Set (c). Advanced Knowledge on D4All and its use

Module	Title	Type	Credits	Objectives
7	Ethics, legislation and privacy	E	1	• ethics, legislation and privacy protection • good practices in matters, ethics and privacy protection
8	Companies and tabor relations	E	2	• implementation of D4All policies within companies. • Corporate Social Responsibility. • techniques and methods for developing successful business models though D4All
9	Consumer electronics and games	E	2	• D4All in consumer electronics and games • methods and techniques for implementing D4All and Universal Accessibility in consumer electronics and games.
10	*Back-end* technologies	E	1	• back-end technologies support for usability and accessibility of ICT services for end users.

D.7.4 Specific Competences

The specific competences acquired under this academic model are the following:

SC.1. The ability to apply *D4All* to the development of new ICTs.
SC.2. The ability to introduce *Universal Accessibility* into the existing ICT devices and systems.
SC.3. The ability to recognize the needs created by the *Supporting Technologies* for *D4All* in ICTs.
SC.4. The ability to apply the required regulations to the subject of accessibility.

	Specific Competences	Modules that develop these competences
SC.1	The ability to apply *D4All* to the development of new ICTs	1, 2, 3, 4, 6, 8, 9, 10
SC.2	The ability to introduce *Universal Accessibility* into the existing ICT devices and systems	1, 2, 3, 4, 6, 8, 9, 10
SC.3	The ability to recognize the needs created by the *Assistive Technologies* for *D4All* in ICTs	1, 2, 3, 5, 7
SC.4	The ability to apply the required regulations to the subject of accessibility	3, 5, 6, 7, 8

In addition, all of them contribute to the transversal competence TC1: Sustainability and social commitment: being aware of and understanding the complexity of economic and social phenomena typical of welfare societies; the ability to relate welfare with globalization and sustainability; the ability to use techniques, technology, economics and sustainability in a balanced and compatible way.

D.8 Three Years' Bachelor of Information and Communications Technology Example

Bachelor of Information and Communications Technology, from the Department of Information Technology, Faculty of Accounting and Informatics, Durban University of Technology, South Africa, http://www.dut.ac.za

D.8.1 Program Goals and Features

The purpose of the Bachelor of Information and Communications Technology (BICT) is to provide students the opportunity to explore a broad range of ICT aspects so they graduate with the knowledge and skills in a variety of key ICT areas for a lifelong career in the ICT domain.

The theoretical perspectives of the BICT degree and its practical orientations aim to develop the technological knowledge and skills that are in high demand throughout the ICT industry. Graduates of this program are conversant with current ICT issues and standards as well as understand and anticipate the ICT evolution from a technical perspective, from an organizational perspective, and from a societal perspective.

This degree seeks to produce ICT graduates who are confident, team players, and sensitive to societal and organizational needs, both within their local contexts and from a global perspective. It also seeks to develop the necessary foundational knowledge and skills to prepare its students to further their post-graduate studies.

D.8.2 Summary of Requirements

The main entrance requirement for this degree is the possession of a South African High School Certificate (National Senior Certificate, Senior Certificate, or National Vocational Certificate), or any qualification deemed equivalent to it by the South African Qualifications Authority (SAQA). National Senior Certificate holders must have a degree endorsement with at least a 50% pass in mathematics and English, and in at least one of the following subjects: physical science, information technology, accounting, and engineering design. Senior certificate holders must have a matriculation exemption with at least a 50% pass in mathematics, in English, and in at least one of the following: physical science, information technology, and accounting. Vocational national certificate holders must have at least 60% in three fundamental subjects including English and mathematics, and at least 70% in four vocational subjects relevant to the field of information technology. Other forms of access to this qualification include the approval of evidence on work experience, on age and maturity, or on recognition of prior learning.

The above summarized entrance requirements seek to ensure that prospective students are well equipped with the necessary mathematics and communication skills before embarking on this program, and that they will be able to take responsibility for their own learning during the program.

This is a three-year program where all modules require the equivalent of four to five weekly contact hours for a semester of around fifteen weeks. The academic year contains two semesters; there are five modules per semester for the first four semesters of this program, but there are only four modules per semester for the last two semesters of this program. All the modules of this program are compulsory except for one third-year module where students can choose an elective from various computing domains such as machine intelligence, graphics, parallel and distributed computing, just to name a few. The program contains a module dedicated to industry exposure during the last semester as well as a third-year project that runs during the first and second semesters of the final year.

The fact that the focus of the program is on computing in general and on information technology in specific does not exempt it from exposing its students to general education modules from other fields of knowledge such as communication, entrepreneurship, law, organizational behavior, just to name a few. The program consists of a total of twenty-eight (28) modules with approximately three quarters of them coming from computing and the remaining quarter coming from other fields of knowledge.

D.8.3 Typical Three-Year Schedule
(Ten courses per year for the first two years, and eight courses in the third year)

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
CMPT 1011	Mathematics for Computing 1A	3	CMPT 1012	Mathematics for Computing 1B	3
CMPT 1014	Introduction to Computing	3	CMPT 1016	Systems Fundamentals	3
CMPT 1015	Software Development Fundamentals	3	CMPT 1013	Discrete Structures	3
BSNS 1011	Business Fundamentals 1A	3	BSNS 1012	Business Fundamentals 1B	3
CMNU 1011	Interpersonal Communication and Self	3	CSED 1011	Cornerstone Education	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 3			**Semester 4**		
CMPT 2012	Programming Languages	3	CMPT 2011	Algorithms and Data Structures	3
CMPT 2013	Networks and Operating Systems	3	CMPT 2014	Computer Organization and Architecture	3
CMPT 2015	Systems Analysis and Design	3	CMPT 2016	Information Management	3
OGBV 2011	Organizational Behaviour	3	CMPT 2017	Information Assurance and Security	3
LAWL 2011	Law for Life	3	ETRP 2011	Entrepreneurship	3
	Total Credits	**15**		*Total Credits*	**15**
Semester 5			**Semester 6**		
CMPT 3011	Project 3A	6	CMPT 3012	Project 3B	6
CMPT 3014	Platform Based Development	3	CMPT 3013	Industry Exposure	3
CMPT 3015	Integrative Programming and Technology	3	CMPT 3017	Social and Professional Issues	3
CMPT 3016	Software Engineering	3	CMPT 302*	Computing Elective	3
	Total Credits	**15**		*Total Credits*	**15**
Electives					
CMPT 3021	Web Systems and Technology	3			
CMPT 3022	Human Computer Interaction	3			

D.8.4 Mapping of this curriculum to subdomains of Essential Curricular Framework

Essential Domains / *Courses*	NET	WMS	IMA	SWF	PFT	IST	UXD	SPA	CSP	GPP
Core										
CMPT 1011										
CMPT 1012										
CMPT 1013										
CMPT 1014				1-3						
CMPT 1015				4						
CMPT 1016					1,3,5					
CMPT 2011				5						
CMPT 2012				6-7						
CMPT 2013	1-7				2					
CMPT 2014					4					
CMPT 2015								1-5		
CMPT 2016			1-7							
CMPT 2017									1-14	
CMPT 3011										1-3
CMPT 3012										7-9
CMPT 3013										10-12
CMPT 3014		1-4				5-6				
CMPT 3015						1-4				
CMPT 3016								6-10		
CMPT 3017										4-6
Electives										
CMPT 3021		5-7								
CMPT 3022							1-8			
Subdomains Covered	1-7	1-7	1-7	1-7	1-7	1-6	1-8	1-10	1-14	1-12

D.9 Australia Example - Bachelor of Information Technology

University of Queensland Australia, Faculty Engineering, Architecture & Information Technology

D.9.1 Program Goals and Features

Students study information & communications technology (ICT) for a variety of reasons – to be a computing professional, to use ICT to be a better scientist, or to empower themselves to better understand the technology behind many of today's careers. Increasingly, employers see an ICT qualification as a sign of academic well-roundedness. ICT drives innovations such as the human genome project, vaccine research, environmental modelling. Key ICT areas include cyber security, mobile computing, cloud computing, and data analytics. Independent job market surveys show that demand for graduates is escalating, along with salaries; industry worries about a shortage of talent.

D.9.2 Curricular Parameters

3 Years, 48 units. A student must complete one of the following:

1. Bachelor IT with no major, comprising:
    a. at least 18 units from Part A; and
    b. at least 6 units from part B, with at least 1 course from part B1; and
    c. at least 8 units from part C; and
    d. the balance from electives from Part D.
2. Bachelor IT with a single major, comprising:
    a. at least 18 units from Part A; and
    b. 14 units from Part E under one heading; and
    c. the balance from electives from parts B, C or D.
3. Bachelor IT with two single majors, comprising:
    a. at least 18 units from Part A; and
    b. 14 units from Part E under one heading; and
    c. 14 units from Part E under another heading where courses that are compulsory in both majors must come from courses from part B or C; and
    d. the balance from electives from parts B, C or D.
4. Bachelor IT with a dual major, comprising:
    a. at least 18 units from Part A; and
    b. 24 units from Part F under one heading; and
    c. the balance from electives from parts B, C or D.
    d. no more than 20 units of level 1 courses.

Part A - Compulsory

7 courses of 2 units each:

- Introduction to Software Engineering
- Design Thinking
- Introduction to Web Design
- Design Computing Studio I - Interactive Technology
- Design Computing Studio 2 - Testing & Evaluation
- Introduction to Information Systems
- Discrete Mathematics

plus at least 4 units from:

- Design Computing Studio 3 - Proposal (2 units)
- Design Computing Studio 3 - Build (2 units)
- Special Projects in Computer Systems and Software Engineering (4 units)

Part B1

2 courses of 2 units each

- Programming in the Large
- Relational Database Systems

Part B2

7 courses of 2 units each

- Numerical Methods in Computational Science
- Introduction to Computer Systems
- Computer Systems Principles and Programming
- Graphic Design
- Digital Prototyping
- Human-Computer Interaction
- Introduction to Bioinformatics

Part C - Advanced Electives

15 courses of 2 units

- Information Analysis and System Design
- Operating Systems Architecture
- Algorithms & Data Structures
- Artificial Intelligence
- Information Security
- Computer Networks I
- Visualization, Computer Graphics & Data Analysis
- High-Performance Computing
- The Software Process
- Social & Mobile Computing
- Advanced Database Systems
- Web Information Systems
- Service-Oriented Architectures
- Scientific Computing: Advanced Techniques and Applications
- Operations Research & Mathematical Planning

1 course of 4 units

- Physical Computing & Interaction Design Studio

Part D - Other Electives (courses of 2 units)

- Genes, Cells & Evolution
- Genetics
- Genomics & Bioinformatics
- Advanced Bioinformatics
- E-Business Systems and Strategy
- Business Information Security
- Chemistry for Science and Engineering
- Introduction to Electrical Systems
- Introduction to Research Practices - The Big Issues
- Mathematical Foundations
- Calculus & Linear Algebra I
- Calculus and Differential Equations
- Calculus & Linear Algebra II
- Linear & Abstract Algebra & Number Theory
- Discrete Mathematics II

- Mathematical Biology
- Electromagnetism and Modern Physics
- Theory & Practice in Science
- Probability & Statistics
- Statistical Modelling & Analysis

Courses offered on an occasional basis, special topics in (2 units each):

- computer science (6 courses);
- software engineering (2 courses);
- design computing (4 courses)

Part E - majors (courses to a total 14 units each) choices:

- Computer Systems and Networks (14 units)
- Software Design (14 units)
- Software Information Systems (14 units)
- User experience design (14 units)

Part F – dual majors (courses of total 24 units)

- Software Information Systems (from part E, 14 units)
- Enterprise information systems (total 10 units)

D.10 Futuristic IT Curriculum – Latin America

Information Technology Program
Administered by an Informatics Department in Latin America

D.10.1 Program Goals and Features

This program leads to a baccalaureate degree in some branch of informatics with an emphasis on information technology (IT). Degree titles vary greatly in Latin America such as ‘ingeniería’ (engineering), ‘computación’ (computing), ‘informática’ (informatics), ‘sistemas’ (systems), ‘tecnologías’ (technologies), ‘información’ (information) and ‘software’. Hence, it is not possible to isolate a degree name such as “information technology” in a conventional manner. A computing department generally offers some foundation courses such as programming; related departments offer the remaining IT courses.

D.10.2 Summary of Requirements

This report proposes a futuristic IT program for Latin American generated from published research [Sab1] and other examples found in this report. The proposed program of study contains six required computing (CMP) courses (22 credits) and 22 required information technology (IT) courses (62 credits). The study program offers flexibility with its three IT elective courses (9 credits); the capstone experience occurs over two courses in the last year, allowing for a substantial and complete practical experience. Students must join an IT center full time for at least eight weeks to complete 280 hours to pass the practical training course. Additionally, the use of English language is not commonly strong among Latin American students, although this language is fundamental in IT degree programs since most technical literature, online courses and videos, and other online IT resources are only available in English and the English language continues to be the language of international business. This curriculum requires 46 courses, with credits distributed as follows.

Requirement Type	No. of Course	Courses	Credits
University Requirements	8	ENG 140, 190, 208, 203, 204	15
		SPN 104, 201	4
		ETH 101	2
		Total Area Credits	**21**
Department Requirements (General)	5	COM 207, 403	4
		BUS 100, 402	4
		ECO 100	2
		Total Area Credits	**10**
Department Requirements (Math & Science)	5	MATH 113, 114, 227	12
		STA 111	3
		PH 103	3
		Total Area Credits	**18**
Department Requirements (Filed Specific)	28	CMPL 104, 106, 220	10
		CMPL 140, 141, 242	12
		ITL 280, 300, 301, 310, 315, 320, 331, 340, 360, 390	34
		ITL 410, 412, 420, 490, 491, 492, 493, 438, 406, 407, 439, 409	32
		IT Electives Courses	9
		Total Area Credits	**97**
Total Credits	**46**	*Total Credits*	**146**

D.10.3 Four-Year Model for Latin America Curriculum

ITL: Offered by an information technology or related department
CMPL: Offered by a related informatics department

Course Code	Course Name	Credit	Course Code	Course Name	Credit
Semester 1			**Semester 2**		
CMPL 104	Discrete Structures	3	CMPL 106	Digital Logic	3
CMPL 140	Computer Programming 1	4	CMPL 141	Computer Programming 2	4
MATH 113	Differential Calculus	4	ITL 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 Credits	**17**		*Total Credits*	**17**
Semester 3			**Semester 4**		
CMPL 220	Computer Organization	4	ITL 360	Operating Systems	4
CMPL 242	Data Structures	4	ITL 320	Introduction to Databases	3
ITL 300	Human-Computer Interaction	3	ITL 315	Technical Support	3
ITL 301	Project Management	4	STA 111	Introduction to Probability & Statistics	3
MATH 227	Linear Algebra and Differential Equations	4	ENG 104	English Language 4	3
ENG 103	English Language 3	3			
	Total Credits	**22**		*Total Credits*	**16**
Semester 5			**Semester 6**		
ITL 340	Computer Networks	4	ITL 420	Database Administration DBMS	3
ITL 310	Cybersecurity Fundamentals	4	ITL 410	IT Security and Risk Management	3
ITL 390	Web Systems	3	ITL 490	Learning & Thinking & Research	1
SPN 201	Expository Writing	2	ITL 409	IT Service Management and Operations	3
COM 207	Communication Skills	2	ETH 101	Professional Ethics	2
ECO 100	Engineering Economics	2	SPN 104	Language Skills	2
ITL 438	Business & Technology Modelling	3	ENG 208	Technical Writing	3
	Total Credits	**20**		*Total Credits*	**17**
Summer Semester					
ITL 491	Practical Training	1			
	Total Credits	**1**			
Semester 7			**Semester 8**		
ITL 331	Fundamentals of n-Tier Architectures	3	ITL 493	Senior Project in Information Technology 2	4
ITL 412	IT Governance	3	ITL xxx	IT Elective 2	3
ITL 492	Senior Project in Information Technology 1	2	ITL xxx	IT Elective 3	3
ITL 406	Cloud Computing	4	COM 403	People Management	2
BUS 100	Intro. to Business Administration	2	ITL 407	Large Data Management	2
ITL xxx	IT Elective 1	3	BUS 402	Entrepreneurship and Innovation in Technology	2
ITL 439	Quality Management Systems	3			
	Total Credits	**20**		*Total Credits*	**16**

D.10.4 Mapping of IT Curricular Framework to Latin America Curriculum

Essential Domains / *Courses*	NET	WMS	IMA	SWF	PET	IST	UXD	SPA	CSP	GPP
CMPL 104										
CMPL 106										
CMPL 140				1-4						
CMPL 141				7						
CMPL 220										
CMPL 242				5-6						
ITL 280	1	1	1		1	1	1	1	1	1
ITL 300							2-8			
ITL 301								2-6		
ITL 310									2-7	
ITL 315								7-10		
ITL 320			2-4							
ITL 331						2-6				
ITL 340	2-7									
ITL 360					2-5					
ITL 390		2-7								
ITL 406	6-7	2-7								
ITL 407			1-7							
ITL 410									8-14	
ITL 412										2-7
ITL 420			5-7							
ITL 438			3					2-6		4-12
ITL 439								7-10		
ITL 490										6-10
ITL 491										8-11
ITL 492										3,4, 6-10
ITL 493										12
Subdomains Covered	1-7	1-7	1-7	1-7	1-5	1-6	1-8	1-10	1-14	1-12

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