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Main Computing Disciplines: Characteristics, Similarities, and Differences

(Computer Engineering, Computer Science, Software Engineering, Information Technology, and Information Systems)

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August 2014, June 2016, August 2018, Dec 2018

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Introduction:

1. Computing has been defined by The Joint Task Force for Computing Curricula 2005 as "*any goal-oriented activity requiring, benefiting from, or creating computers.* [ACM et al, 2006]". This is a very broad definition, ranging from designing and building hardware and software systems, up to using these systems to store and process data, as well as to perform or support different activities. The breadth of the computing discipline is evidenced also by the fact that it strongly uses knowledge and skills from other disciplines, like mathematics, science, engineering, and business. Given this wide spectrum of knowledge and skills, a potential computing professional needs to focus on particular areas of this discipline, as it is not possible to become proficient in all of them. [ACM et al, 2006]

2. In fact, computing is really a family of disciplines consisting of several more specific computing disciplines, like Computer Engineering (CE), Computer Science (CS), Software Engineering (SE), Information Technology (IT) and Information Systems (IS). Originally there were only three kinds of computer-related disciplines: Electrical Engineering for students interested in hardware, Computer Science for student interested in programming, and Information Systems for students interested in using hardware and software to solve business problems. In the late 1970s, Computer Engineering (CE) emerged from Electrical Engineering to focus on the design and programming of chips that control devices. Software Engineering emerged from Computer Science in the 1980s and 1990s to design and create comprehensive applications software, combining Computer Science principles and techniques with engineering practices. Information Technology emerged in the late 1990s, to take care of the computing infrastructure in organizations, a gap not being addressed by CE, CS, SE, and IS. [ACM et al, 2006]

    a. Additional computing-related fields have emerged and/or become more relevant during the last two decades, and some are being seriously considered for inclusion under the computing family of disciplines. One of them is Cybersecurity or Cyber Science. Another one is Data Analytics or Data Science. Regarding Cybersecurity, ABET's Computing Accreditation Commission already approved their respective program criteria for programs in Cybersecurity. These criteria had been opened for public review and comments for some time and were finally adopted in November 2018. Several computing programs have been "piloting" these criteria, for both current programs as well as programs under development. [ABET, 2017]

3. The increase in the number of computing disciplines has complicated student decisions regarding which discipline to study. Universities also face complications regarding which of these disciplines to address through their academic programs. The complications may be even higher when universities want to offer programs in more than one of these disciplines, or through combinations of them. Employers face difficulties when preparing job descriptions and hiring candidates. Parents and academic advisors also face difficulties when advising students on which discipline to study. There is definitely a need for explanation and clarification.

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Introduction:

a. One fundamental example about the need for clarification is the term "Information Technology" itself. This term is used in two related but different contexts: to refer to all of computing, and as a particular computing discipline. That's why we hear about the Information Technology industry, and also about Information Technology programs. The first one refers to the computing family of disciplines and the second one refers to a particular discipline within Computing. People not familiar with Computing may get confused by things like this one.

b. Another example is the term "Software Engineer", which is frequently used to designate programmers, IT specialists, and other computing professionals, which are not necessarily graduates from a School of Engineering.

4. It is also important to clarify the relationship between academic disciplines and academic programs. A discipline is a common, clearly defined and differentiated body of knowledge, which involves formality. An academic program should follow one discipline or a combination of disciplines, but they are not obliged to do so. Therefore, you may find a computing academic program which is, for example, a combination of Computer Engineering, Computer Science and Software Engineering. A good question to ask when analyzing a computing academic program is which computing discipline it follows most.

5. One of the goals of the Government of Puerto Rico is to promote the growth of the Information Technology sector. In order to do so, it is essential to address the development of computing professionals. Several things could be done around this. One of them is to help people understand what the main computing disciplines are, as well as their differences and similarities. This document is intended to contribute towards this. We expect it to be helpful to current and potential students, educators, academic advisors, parents, employers, and others.

Comparison between the main computing disciplines:

#	Discipline	Brief description	Examples of topics emphasized	Location	Who should study this discipline
1	Computer Engineering (Computer Engineering emerged from Electrical	Computer Engineering focuses on the design, construction, and programming of the chips that digitally control many	Computer architecture and organization, Digital logic, Analysis of technical requirements, Embedded systems,	CE programs are usually located in an engineering school.	Suitable for students who are mostly interested in hardware design. For example, students who want to design or build computers or computing

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	Engineering during the late 1970s, and the 1980s, although it was in the 1990s that it grew to become a discipline in itself.)	kinds of devices, including computers. Examples of these devices are cell phones, car computers, security devices, and internet-connected home devices. It also focuses in the development of new knowledge and techniques. Since its emphasis is mostly in hardware, software is not addressed as a goal by itself, but as an important component embedded into hardware to make it work as desired. CE has a strong engineering orientation.	Distributed systems, Computer systems engineering, Operating system principles, and Programming fundamentals. Significant attention is placed to engineering topics, like Circuits and systems, Digital signal processing, Hardware testing, Fault tolerance, and also to mathematical foundations.		devices. Also, students interested in the type of programming which is embedded in these devices to control their behavior.
2	Computer Science (Computer Science is one of the three original computing disciplines, first appearing as a discipline in the 1960s.)	Computer Science focuses in developing and maintaining computer software. On one side, it focuses in the development of new knowledge and techniques to enhance and make more efficient the computing discipline. Additionally, CS focuses in the application of current knowledge and techniques to	Programming fundamentals, Algorithms, Programming languages, Computer architecture and organization, Artificial intelligence, Information management theory and practice, Software design, Security issues and principles, Data structures, and Operating	CS programs are usually located in the School of Sciences.	Suitable for students who are highly interested in programming. Also, for students interested in research, as well as in the theoretical and formal aspects of computer software.

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		design and create "infrastructure software", like operating systems, data base management systems, browsers, and search engines. It works less in the creation of software applications, and it typically does not work in the deployment and support of software applications for organizations. CS is probably the more theoretical and research-oriented computing discipline.	systems principles and design. Significant attention is placed to apply mathematical and scientific knowledge to solve computing problems.		
3	Software Engineering (Software Engineering emerged from Computer Science in the 1980s and 1990s. The term "Software Engineering" is used in two related but different contexts: as a job title ("Software Engineer"), and as a computing discipline ("Software Engineering"). As a job title, "Software	Same as Computer Science does, Software Engineering focuses in developing and maintaining computer software. SE combines computer science principles and techniques with engineering practices to design and create comprehensive and large-scale "applications software", like Inventory Control systems, Airline Reservation systems, and Loan Origination and Processing systems.	Programming fundamentals, Algorithms, Programming languages, Computer architecture and organization, Information management theory and practice, Software design, Security issues and principles, Operating systems principles and design, Engineering foundations and economics for software, Software design, Software verification and	SE programs are located in several schools, including the Engineering School, and the School of Sciences. It is sometimes located also within the Computer Science department, either as a separate program or combined with Computer Science.	Suitable for students who are highly interested in designing and programming comprehensive and large-scale applications software, to be implemented in organizations or used by individuals. Also, for students interested in combining computing knowledge and techniques with engineering practices.

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	Engineer" is frequently used to designate programmers, IT specialists, and other professionals which are not necessarily engineers.)	It emphasizes the use of available computing knowledge and techniques to create new software products, rather than the creation of new knowledge and techniques for the computing discipline. Like other engineering disciplines, it focuses on rigorous methods for designing and building things that reliably do what they're supposed to do.	validation, and Systems integration.		
4	Information Technology (Information Technology emerged in the late 1990s to fill a gap not being addressed by CS, SE, and IS. The term "Information Technology" is used in two related but different contexts: to refer to all of computing, and as a particular computing discipline.)	Information Technology focuses on deploying and supporting the computing infrastructure in organizations. That is, deploying and supporting servers, desktops, communication networks, operating systems, and platform applications (like office systems, email and web related software). It makes sure that computing infrastructure is suitable, is available, and works reliably. It puts more emphasis on the integration of hardware, software, and communication networks into a technological	Configuring and operating the components of the computing infrastructure in an organization, Operating systems configuration and use, Security implementation and management, Design and implementation of local and wide area networks, Hardware warranty, maintenance and support, Installation and configuration of infrastructure software, Analysis of technical requirements, Web site	IT programs are located in several schools, including the Engineering School, the Business School, and an independent school.	Suitable for students who are highly interested in deploying and supporting the use of technology in organizations. (Implementing and operating servers, desktops, local area networks, wide area networks, and other components of the computing infrastructure in organizations requires more technical skills and less client-facing skills. But IT specialists also provide technical support to users of the computing infrastructure, in which case students must also like to interact with people, besides interacting with technology.)

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		solution, and less emphasis on the information (or contents) component of the solution. IT is oriented towards the deployment and support in organizations of the products already developed by CE, CS, and SE, and not towards the development of new products.	development and maintenance. (Programming is emphasized only to ensure students understand how it works, although some IT academic programs emphasize application development.)		
5	Information Systems (Information Systems is one of the three original computing disciplines, first appearing in the 1960s.)	Information Systems emphasizes the deployment and support of computing applications to enable organizational processes in order to make organizations more effective, efficient, and competitive. IS specialists select and acquire, the software products developed by Computer Scientists, and the comprehensive applications developed by Software Engineers, deploy them on top of the infrastructure deployed by Information Technology specialists, and integrate these products into a functional solution. They make sure that	Business process analysis and reengineering, Application requirements definition, Applications procurement, deployment, training, and support, E-Business applications, Project management, Business intelligence and data mining, Managing data centers, and Data security and control. Programming and computing infrastructure are emphasized only to ensure students understand how these components work and fit together, although some	IS programs are usually located in the School of Business, although recent trends have also located them in other functional areas like Public Administration and Health Administration.	Suitable for students who are interested in procuring, implementing and supporting computing applications within an organizational context. In order to do so, students must be interested in obtaining a combination of both technical and functional (Accounting, Marketing, Strategic management, etc.) knowledge, which would enable them to act as a bridge between the more technical and the functional staff in organizations. IS students must also like to interact with people, besides interacting with technology.

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		all computing resources are properly integrated, supported and used, so that they produce the information necessary to enable effective and efficient organizational operations.	IS academic programs emphasize application development and computing infrastructure. Significant attention is placed to functional topics, like organizational theory, organizational behavior, business processes, and industry regulations.		

Orientation of the main computing disciplines towards product development, product deployment and user support:								
Discipline	Products developed					Products deployed (implemented)		
	Hardware	Hardware-embedded software	Creation of new knowledge &	Infrastructure software (OS, tools, platforms)	Application software	Hardware infrastructure	Infrastructure software (OS, tools, platforms)	Applications software
Computer Engineering	High	High	High	(No standalone software development)		(No direct deployment to users)		
Computer Science	(No hardware development)		High	High	Low	(No direct deployment to users)		
Software Engineering	(No hardware development)		Low	Low	High	Low	Low	Low
Information Technology	(No hardware/software development)					High	High	Low
Information Systems	(No hardware/software development)					Low	Low	High

Orientation of the main computing disciplines towards product development, product deployment and user support (continued):				
Discipline	User support provided to products already deployed			
	Hardware infrastructure support	Infrastructure software support	Applications software support	Functional support
Computer Engineering	(No direct support to users)			
Computer Science	(No direct support to users)			
Software Engineering	(No direct support to users)			
Information Technology	High	High	Low	
Information Systems	Low	Low	High	High

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