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Comparativa de la guía curricular ACM/IEEE CE2004 y ACM/IEEE CE2016

ACM/IEEE CE2004 and ACM/IEEE CE2016 curricular guide comparative

Comparação do guia curricular ACM / IEEE CE2004 e ACM / IEEE CE2016

Joel Ayala de la Vega
Universidad Autónoma del Estado de México, México
Joelayala2001@yahoo.com.mx
Orcid ID: 0000-0003-3279-4143

Irene Aguilar Juárez
Universidad Autónoma del Estado de México, México
ireneico@gmail.com
Orcid ID: 0000-0003-4747-0336

Resumen

Las ciencias de la computación se desarrollan día a día a pasos agigantados. Esto obliga a toda institución de educación superior que imparta una licenciatura enfocada al cómputo a realizar una revisión curricular de forma continua. Para ello se requiere un criterio a seguir que permita hacer una comparación con lo que cada universidad está desarrollando.

La Association for Computing Machinery (ACM) y el Institute of Electrical and Electronics Engineers (IEEE) editaron dos guías curriculares para el área de ingeniería en computación, a saber, la CE2004 y la CE2016. Ambas guías permiten observar los cambios significativos a través del tiempo y ofrecen una referencia curricular. Además, en el apéndice B de la guía CE2016 se muestran currículos de universidades estadunidenses y de la Unión Europea, lo que, a su vez, permite hacer una comparativa con respecto a algunos currículos de universidades latinoamericanas en relación a horas por semana, clases y número de unidades de aprendizaje. Al contrastar las dos guías, se pueden observar grandes cambios existentes en esta área a nivel internacional en los últimos 12 años, reforzando la importancia de una revisión curricular. Al analizar los currículos del apéndice B, se observa de forma general una gran diferencia entre los currículos de universidades estadunidenses y europeas con respecto a los de universidades latinoamericanas.

Palabras clave: ACM, comparativa curricular, evaluación curricular IEEE, ingeniería en computación.

Abstract

Computer Science develops day by day in leaps and bounds. This obliges every high education institution to teach a bachelor's degree focused on computation to perform a curricular review on a continuous basis. For this, a criterion to be followed is required in order to make a comparison with what each university is developing.

The Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE) published two curricular guides (CE2004 and CE2016) for Computer Engineering area (CE). This allows to observe the significant changes over time and gives a curricular reference. In addition, Appendix B of the CE2016 guide, shows curricula of United States and European Union Universities; allowing to make comparisons between Latin American Universities curriculums in relation to hours/week classes and number of Learning Units. By contrasting both guides, it can be observed the great changes that have taken place in CE at an international level in the last twelve years, reinforcing the importance of a continuous revision of the CE curriculum. When appendix B curricula is analyzed, a general difference between US and European universities compared with Latin American universities can be observed.

Keywords: ACM, Curriculum Comparison, Curriculum Assessment, IEEE, Computer Engineering.

Resumo

A informática desenvolve dia a dia a passos largos. Isso exige que qualquer instituição de ensino superior ensine um diploma de bacharel focado em computação para realizar uma revisão curricular de forma contínua. Isso requer um critério a ser seguido que permita uma comparação com o que cada universidade está desenvolvendo.

A Associação para Máquinas de Computação (ACM) e o Instituto de Engenheiros Elétricos e Eletrônicos (IEEE) publicaram dois guias curriculares para a área de engenharia informática, nomeadamente CE2004 e CE2016. Ambos os guias permitem observar as mudanças significativas ao longo do tempo e oferecer uma referência curricular. Além disso, o Apêndice B do guia CE2016 mostra os currículos das universidades dos EUA e da União Européia, o que, por sua vez, permite comparações com alguns currículos de universidades latino-americanas em relação a horas por semana, aulas e número de unidades de aprendizagem. Ao contrastar os dois guias, pode-se observar grandes mudanças nesta área a nível internacional nos últimos 12 anos, reforçando a importância de uma revisão curricular. Ao analisar o currículo do Apêndice B, há uma diferença geral entre os currículos das universidades dos EUA e da Europa em relação às universidades latino-americanas.

Palavras-chave: ACM, currículo comparativo, avaliação curricular IEEE, engenharia informática.

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Introduction

The concept called quality assurance is defined as the set of planned and systematic actions implemented under a quality system, which is necessary to provide adequate confidence that a product will meet the given quality requirements (International Organization for Standardization, 2017).

Transferred to the field of higher education, universities must take charge of the processes that allow the assurance of quality in various aspects, such as teaching and learning processes, services provided by the institution, internal management and compliance with the legal regulations, among others. A manifestation of university quality assurance is given by the curricular review processes, which may originate in an update required by needs, for example, improve the control process, include changes in professional discipline and include changes in strategies teaching. If the level of change to the curriculum is slight, it may be that an update to the subject programs is sufficient; but if the changes are profound, it will be necessary to carry out a curricular redesign (Icarte & Labate, 2016).

Higher education institutions have the responsibility to train highly qualified professionals, in this case, in the domain of information technologies that can respond to the challenges that emerge every day in society. Therefore, a permanent revision to the curricular structure is required in order to guarantee this quality that contemporary society requires.

The Institute of Electrical and Electronics Engineers (IEEE) is the largest and most prestigious engineering organization in the world, as well as a leader in the publication of literature in electrical engineering, electronics and related branches (IEEE, s.f.). The Association for Computing Machinery (ACM) was founded in 1947 as the first scientific and educational society about computing (ACM, s.f.). Both professional organizations carried out the first edition of a curricular guide for the area of computer engineering in December 2004, the CE2004, and subsequently published a review of this in December 2016, the CE2016, according to scientific, social and professional criteria.

It should be noted that a comparative study is an additional source of information to make a curricular design more in line with current requirements; It also serves as a basis for making possible changes to a syllabus at the undergraduate level in any higher education institution.

Problem Statement

In recent years there have been significant changes (quantitative and qualitative) both in the scientific area and in the technical area. This has produced a transformation in the social and productive processes through the incorporation of new technological elements, making new paradigms of knowledge and information appear in society. Therefore, a constant and general revision of the curricular contents in the universities is demanded to detect if the knowledge, abilities and skills that are intended to develop in the student are those required by the current society and if these respond to the internationalization of the economy.

The current curriculum should plan the training of an individual who is trained to provide their services not only nationally but also internationally. In other words, it must have a transnational approach, outside borders, and with a command of the language that facilitates communication and proper introduction into culture; all this in guarantee of a successful professional practice. To achieve this goal, substantial changes are required, including changes to the curricular model, in the sense of overcoming the so-called rigid curriculum to give way to semi-flexible, flexible or modular curricula (IEEE, ACM, 2016).

An old dilemma to solve in the curricular design is condensed in a sentence said repeatedly by the students: "to learn in the present knowledge of the past to apply them in the future". The revision of the curriculum should lead to offer knowledge of the present to the students of the present (Torres Estevéz, 2002).

The basis of the comparison, on the other hand, is conceived as an activity that allows improving the quality of teaching through the improvement and updating of the curriculum. In this way, the fact of observing the changes proposed by the ACM and the IEEE allows us to reflect on the improvement of curricula within educational institutions.

ACM/IEEE CE2004 and ACM/IEEE CE2016 Reports

Next, a comparison between the CE2004 and CE2016 guides will be made, indicating the most important points following the criteria proposed by those who prepared them. A starting point is that both guides coincide with the definition of the computer engineering discipline.

> Computer engineering is the discipline that incorporates both science and technology in the design, construction, implementation and maintenance of software components and hardware of modern computer systems and computer controlled equipment. Computer engineering has traditionally been seen as a combination of computer science and electrical engineering. (ACM/IEEE, 2016) (ACM/IEEE, 2004)

In addition to the above, both reports provide some background in the field of computer engineering and explain the evolution of this discipline. They also describe the expectations of the graduates and show how they differ from those coming from computer disciplines.

The basis of these reports is a fundamental body of knowledge from which an institution can develop or modify a curriculum to meet their needs. It is noteworthy that they contain different areas of knowledge that are applicable to all computer engineering from anywhere in the world. Each area of knowledge has its theme and a set of knowledge units. Certain areas of knowledge are identified as a "core" that must appear in every curriculum; the remaining areas are supplementary. A computer engineering curriculum that contains only nuclear units is considered incomplete.

On the other hand, a computer engineering program should contain sufficient introductory, intermediate and advanced courses based on your body of knowledge. Both reports request breadth and depth in science and mathematics.

The curriculum should also emphasize professional practice, legal and ethical issues and the social context in which graduates implement engineering designs. In addition, you must emphasize problem solving and critical thinking skills, personal (soft) skills, and oral and written communication. Teamwork and a variety of laboratory experiences are equally fundamental to the study of computer engineering.

Characteristics of a computer engineer

Distinctions

The two reports mark an important distinction between computer engineers, electrical engineers, other computer professionals and engineering technicians. While these distinctions are sometimes ambiguous, computer engineers generally must possess the following three characteristics:

1. The ability to design computers, computer systems and networks that include hardware and software, as well as their integration to solve new engineering problems. In this context, design refers to a skill level beyond "assembly" or "configuration" systems.
2. A wide range of knowledge in mathematics and engineering sciences.
3. Acquisition and maintenance of a preparation for professional practice in engineering

Professionalism

Graduates should understand the responsibilities associated with the practice of engineering, including the professional, social and ethical context in which they do their work. Such responsibilities often involve complicated commitments that involve fiscal and social issues. This social context also includes a series of legal and economic issues: intellectual property rights, security and privacy issues, responsibility, technological access and global implications and the uses of technologies.

Professionalism and ethics are critical elements, since the engineering approach to design and development makes the social context fundamental for studies in the field. It is up to all computer engineers to maintain the principles of their profession and adhere to the codes of professional practice.

Ability to design

Engineering is based, to a large extent, on design capacity. In this sense, the International Association for Education in Technology (ITEEA) defines engineering design as "the systematic and creative application of scientific and mathematical principles for practical purposes such as the design, manufacture and operation of structures, machines, processes and efficient and economic systems "(ITEEA, 2018).

Computer engineers apply the theories and principles of science and mathematics to design hardware, software, networks and processes, as well as to solve technical problems. The continuous advances in computers and digital systems have created opportunities for professionals capable of transferring these developments to a wide range of applications in engineering.

Amplitude of knowledge

The curricular content can vary widely among the programs and even among the students of the same program. The courses related to computers typically come from the organization and architecture of these and are related to algorithms, programming, databases, networks, software engineering and communications. Courses related to electrical engineering usually come from circuits, from digital logic, microelectronics, signal processing, electromagnetism, control systems and integrated circuit design. The fundamental areas usually include basic sciences, mathematics for discrete and continuous domains and applications of probability and statistics.

At one extreme, a computer engineering degree program could provide opportunities for your students to study a broad range of topics that span the entire field. At another extreme, there may be programs that focus on a specific aspect of computer engineering and cover it with great depth.

Despite the differences in emphasis and content, there are certain common elements that one should expect from any program in this area. Therefore, from a higher level perspective, several characteristics can be reasonably anticipated in all graduates in computer engineering. These characteristics are listed below:

- *System level perspective:* graduates should appreciate the concept of a computer system, the design of hardware and software for that system and the processes involved in its construction, analysis and maintenance throughout its life.
- *Depth and breadth:* graduates must have familiarity with thematic areas in the full scope of the discipline.
- *Design experiences:* graduates must have completed a sequence of design experiences, including elements of hardware and software and their integration, based on previous work and with at least one important project.
- *Use of tools:* graduates should be able to use a variety of computer-based and laboratory tools for the analysis and design of computer systems.
- *Professional practice:* graduates must understand the social context in which engineering is practiced, as well as the effects of engineering projects on society.
- *Communication skills:* graduates should be able to communicate their work in appropriate formats (written, oral and graphic) and critically evaluate materials presented by others in those same formats.

Basic principles of computer engineering

Core units comprise knowledge and skills that every computer engineer must have; the supplementary units, knowledge and skills that reflect additional work and cover the specific needs of each program.

CE2004 and CE2016 agree on the basic principles of computer engineering in the following way:

- Computer engineering is a broad and developing field.
- It is a different discipline with its own body of knowledge, its own ethos and its own practices.
- It is based on a wide variety of other disciplines. The teaching of computer engineering is solidly based on the theories and principles of computing, mathematics and engineering, and applies these theoretical principles to design hardware, software, networks and equipment and computerized instruments to solve technical problems in various areas.
- The rapid evolution of computer engineering requires a continuous revision of the corresponding curriculum.
- The development of a computer engineering curriculum should be sensitive to technological changes, to new developments in pedagogy and to the importance of lifelong learning.
- The computer engineering work group should try to identify the fundamental skills and knowledge that all graduates in this discipline must possess.
- The necessary core of the knowledge set should be as small as reasonably possible.
- Computer engineering should include the design and experiences of appropriate and necessary laboratories.
- The computer engineering curriculum should include preparation for professional practice as an integral component.
- The computer engineering report should include discussions on strategies and tactics for its implementation along with high-level recommendations.
- The final report of this discipline should strive to be international in scope.

In addition, the CE2016 proposal considers it helpful to emphasize the following points:

- The basic components refer to the knowledge and skills that all students of all computer engineering programs must achieve. The absence of some basic components of learning does not imply a negative judgment about its value, importance or relevance. Rather, it simply means that the learning outcome is not a requirement of every student in all degree programs in that area.

- Knowledge areas are not courses and the basic components do not constitute a complete curriculum. Each program may choose to cover the basic units of knowledge in several ways.
- Additional technical areas are needed, as well as support for math, science and general studies subjects to produce a competent computer engineer.

Evaluation of the time needed to cover a unit

The steering committee of the CE2016 has chosen to express the time in hours, specifically in basic hours. This corresponds to the time in class required to present the material within a unit of knowledge in a traditional conference-oriented format. Therefore, a "central time" or a "conference time" is a period of 50 minutes.

To dispel any possible confusion it is important to underline the following observations on the use of conference hours as a measure.

- The hours specified for a laboratory component in a curriculum usually have three hours of contact laboratory equivalent to one hour of class. That is, 150 minutes (three contact laboratory hours of 50 minutes) is equivalent to one hour of class. This calculation varies from one institution to another.
- As a general guideline, the amount of work outside of class is approximately three times the time in the class. Therefore, an enumerated unit that requires three hours typically involves a total of twelve hours (three in class and nine outside class).
- The hours listed for a knowledge unit represent a minimum level of coverage.

Summary of the body of knowledge

Table 1 shows the basic core of both the 2004 curriculum and the 2016 curriculum. Table 2 and Table 3 list the knowledge areas that are part of the body of the knowledge areas of the 2004 and 2016 curricula, along with their associated units of knowledge. The tables also show the basic hours (class hours) associated with each area and each unit. For example, in Table 3, where "CE-ESY-5 Parallel Input and Output [3]" is mentioned, it is indicated that the "Parallel Input and Output" should have a relative emphasis measured by three basic teaching hours and is the fifth knowledge unit in the area of knowledge "Embedded Systems" (core of a computer engineering program), with a relative emphasis measured by a three-hour conference. The absence of a number such as "[3]" means that the unit of knowledge is not basic; therefore, it is complementary.

Tabla 1. Núcleo básico para las versiones 2004 y 2016.

CE2004		CE2016	
CE-ALG	Algoritmos	**CE-CAE**	Algoritmos computacionales
CE-CAO	Arquitectura y organización de computadoras	**CE-CAO**	Arquitectura y organización de computadoras
CE-CSE	Ingeniería de sistemas computacionales	**CE-SPE**	Ingeniería de sistemas y proyectos
CE-DSP	Proceso de señales digitales	**CE SGP**	Procesamiento de señales
CE-ESY	Sistemas incrustados	**CE ESY**	Sistemas incrustados
CE-ELE	Electrónica	**CE-CAE**	Circuitos y electrónica
CE-SPR	Cuestiones sociales y profesionales	**CE-PPP**	Preparación para la práctica profesional
CE-NWK	Redes computacionales	**CE-NWK**	Redes computacionales
CE-DIG	Lógica digital	**CE-DIG**	Diseño digital
CE-OPS	Sistemas operativos	**CE-SRM**	Gestión de recursos de sistemas
CE DBS	Sistemas de bases de datos	**CE SWD**	Diseño de *software*
CE CSG	Circuitos y señales	**CE SEC**	Seguridad de la información
CE HCI	Interacción hombre-máquina		
CE PRF	Fundamentos de programación		
CE SWE	Ingeniería de *software*		
CE VLS	Diseño y fabricación de VLSI		
CE DSC	Estructuras discretas		
CE PRS	Probabilidad y estadística		

(ACM/IEEE, 2004) (ACM/IEEE, 2016)

Tabla 2. El Cuerpo de Conocimientos de Ingeniería en Computación CE2004

Ingeniería en computación. Áreas y unidades de conocimiento	
CE-ALG Algoritmos [30 horas] CE-ALG0 Historia y visión general [1] CE-ALG1 Análisis algorítmico básico [4] CE-ALG2 Estrategias algorítmicas [8] CE-ALG3 Algoritmos de computación [12] CE-ALG4 Algoritmos distribuidos [3] CE-ALG5 Complejidad algorítmica [2] CE-ALG6 Teoría básica de la computabilidad	**CE-CAO Arquitectura y organización de la computación** [63 horas] CE-CAO0 Historia y visión general [1] CE-CAO1 Fundamentos de la arquitectura de la computación [10] CE-CAO2 Aritmética computacional [3] CE-CAO3 Organización y arquitectura de sistemas de memoria [8] CE-CAO4 Interfaz y comunicación [10] CE-CAO5 Subsistemas de dispositivos [5] CE-CAO6 Diseño de sistemas de procesamiento [10] CE-CAO7 Organización de la CPU [10] CE-CAO8 Rendimiento [3] CE-CAO9 Modelos de sistemas distribuidos [3]
CE-CSE Ingeniería de Sistemas [18 horas de núcleo] CE-CSE0 Historia y visión general [1] CE-CSE1 Ciclo de vida [2] CE-CSE2 Análisis y elicitación de requisitos [2] CE-CSE3 Especificación [2] CE-CSE4 Diseño arquitectónico [3] Pruebas CE-CSE5 [2] CE-CSE6 Mantenimiento [2] CE-CSE7 Gestión de proyectos [2] CE-CSE8 Diseño concurrente (*hardware* / *software*) [2] CE-CSE9 Implementación del CE-CSE10 Sistemas especializados CE-CSE11 Fiabilidad y tolerancia a fallos	**CE-CSG Circuitos y Señales** [43 horas-núcleo] CE-CSG0 Historia y visión general [1] CE-CSG1 Cantidades eléctricas [3] CE-CSG2 Circuitos y redes resistivas [9] CE-CSG3 Circuitos reactivos y redes [12] CE-CSG4 Respuesta de frecuencia [9] CE-CSG5 Análisis sinusoidal [6] CE-CSG6 Convolución [3] CE-CSG7 Análisis de Fourier CE-CSG8 Filtros CE-CSG9 Transformadas de Laplace
CE-DBS **Sistemas de Bases de Datos** [5 horas] CE-DBS0 Historia y visión general [1] * CE-DBS1 Sistemas de base de datos [2] * CE-DBS2 Modelado de datos [2] * CE-DBS3 Bases de datos relacionales * CE-DBS4 Lenguajes de consulta de la base de datos * CE-DBS5 Diseño de bases de datos relacionales * CE-DBS6 Procesamiento de transacciones * CE-DBS7 Bases de datos distribuidas * CE-DBS8 Diseño de bases de datos físicas	CE-DIG **Lógica Digital** [57 horas] CE-DIG0 Historia y visión general [1] CE-DIG1 Teoría de conmutación [6] CE-DIG2 Circuitos lógicos combinacionales [4] CE-DIG3 Diseño modular de circuitos combinacionales [6] CE-DIG4 Elementos de memoria [3] CE-DIG5 Circuitos lógicos secuenciales [10] CE-DIG6 Diseño de sistemas digitales [12] CE-DIG7 Modelado y simulación [5] CE-DIG8 Verificación formal [5] CE-DIG9 Modelos de fallas y pruebas [5] CE-DIG10 Diseño para las pruebas
CE-DSP Procesamiento de señal digital [17 horas] CE-DSP0 Historia y visión general [1]	**CE-ELE Electrónica** [40 horas] CE-ELE0 Historia y visión general [1]

CE-DSP1 Teorías y conceptos [3]	CE-ELE1 Propiedades electrónicas de los materiales [3]
CE-DSP2 Análisis de espectros digitales [1]	CE-ELE2 Diodos y circuitos de diodo [5]
CE-DSP3 Transformada discreta de Fourier [7]	CE-ELE3 Transistores y polarización MOS [3]
CE-DSP4 Muestreo [2]	CE-ELE4 Familias de lógica MOS [7]
CE-DSP5 Transformadas [2]	CE-ELE5 Transistores bipolares y familias lógicas [4]
CE-DSP6 Filtros digitales [1]	CE-ELE6 Parámetros de diseño y problemas [4]
CE-DSP7 Señales discretas de tiempo	CE-ELE7 Elementos de almacenamiento [3]
CE-DSP8 Funciones de la ventana	CE-ELE8 Interfaz de familias lógicas y buses estándar [3]
CE-DSP9 Convolución	CE-ELE9 Amplificadores operacionales [4]
CE-DSP10 Procesamiento de audio	CE-ELE10 Modelado y simulación de circuitos [3]
CE-DSP11 Procesamiento de imágenes	CE-ELE11 Circuitos de conversión de datos
	CE-ELE12 Fuentes electrónicas de tensión y corriente
	CE-ELE13 Diseño del amplificador
	CE-ELE14 Bloques de construcción de circuitos integrados
CE-ESY Sistemas incrustados [20 horas]	**CE-HCI Interacción Hombre-Computador** [8 horas]
CE-ESY0 Historia y visión general [1]	CE-HCI0 Historia y visión general [1]
CE-ESY1 Microcontroladores integrados [6]	CE-HCI1 Fundamentos de la interacción hombre-computadora [2]
CE-ESY2 Programas integrados [3]	CE-HCI2 Interfaz gráfica de usuario [2]
CE-ESY3 Sistemas operativos en tiempo real [3]	CE-HCI3 Tecnologías de E / S [1]
CE-ESY4 Computación de baja potencia [2]	CE-HCI4 Sistemas inteligentes [2]
CE-ESY5 Diseño confiable del sistema [2]	CE-HCI5 Evaluación de *software* centrada en el ser humano
CE-ESY6 Metodologías de diseño [3]	CE-HCI6 Desarrollo de *software* centrado en el ser humano
CE-ESY7 Soporte de herramientas	CE-HCI7 Interactivo gráfico de diseño de interfaz de usuario
CE-ESY8 Multiprocesadores integrados	CE-HCI8 Programación gráfica de la interfaz de usuario
CE-ESY9 Sistemas incrustados en red	CE-HCI9 Gráficos y visualización
CE-ESY10 Sistemas de interconexión y señalización mixta	CE-HCI10 Sistemas multimedia
CE NWK Redes Computacionales [21 HRS]	**CE OPS Sistemas Operativos** [20 HORAS]
CE NWK0 Historia y visión general [1]	CE OPS0 Historia y visión general [1]
CE NWK1 Arquitectura de comunicación [3]	CE OPS1 Principios de diseño [5]
CE NWK2 Protocolos de comunicación [4]	CE OPS2 Concurrencia [6]
CE NWK3 Redes de área amplia y local [4]	CE OPS3 Calendarización y envío [3]
CE NWK4 Computo cliente-servidor [3]	CE OPS4 Administración de la memoria [5]
CE NWK5 Seguridad e integridad de datos [4]	CE OPS5 Administración de dispositivos
CE NWK6 Computo móvil e inalámbrico [2]	CE OPS6 Protección y seguridad
CE NWK7 Evaluación de desempeño	CE OPS7 Sistema de archivos
CE NWK8 Comunicación de datos	CE OPS8 Evaluación de desempeño del sistema
CE NWK9 Comunicación de datos.	
CE NWK10 Compresión y descompresión.	
CE PRF Fundamentos de Programación [39 H]	**CE-SPR Temas Sociales y Profesionales** [16 h]
CE PRF0 Historia y visión general [1]	CE-SPR0 Historia y visión general [1]
CE PRF1 Paradigmas de programación [5]	CE-SPR1 Política pública [2]
CE PRF2 Constructores de programación [7]	CE-SPR2 Métodos y herramientas de análisis [2]
CE PRF3 Algoritmos y solución de problemas [8]	CE-SPR3 Responsabilidades profesionales y éticas [2]

CE PRF4 Estructuras de datos [13] CE PRF5 Recursión [5] CE PRF6 Programación Orientada a Objetos CE PRF7 Programación concurrente y manejo de eventos CE PRF8 Uso de API´s	CE-SPR4 Riesgos y responsabilidades [2] CE-SPR5 Propiedad intelectual [2] CE-SPR6 Privacidad y libertades civiles [2] CE-SPR7 Crimen informático [1] CE-SPR8 Cuestiones económicas en la informática [2] CE-SPR9 Marcos filosóficos
CE-SWE Ingeniería de *Software* [13 horas] CE-SWE0 Historia y descripción general [1] CE-SWE1 Procesos de *software* [2] CE-SWE2 Requisitos y especificaciones del *software* [2] CE-SWE3 Diseño de *software* [2] CE-SWE4 Pruebas y validación de *software* [2] CE-SWE5 Evolución del *software* [2] CE-SWE6 Herramientas y entornos de *software* [2] CE-SWE7 Traducción de idiomas CE-SWE8 Gestión de proyectos de *software* CE-SWE9 Tolerancia a fallos de *software*	**CE-VLS Diseño y fabricación de VLSI** [10 horas] CE-VLS0 Historia y visión general [1] CE-VLS1 Propiedades electrónicas de los materiales [2] CE-VLS2 Función de la estructura básica del convertidor [3] CE-VLS3 Estructura de lógica combinacional [1] CE-VLS4 Estructura de lógica secuencial [1] CE-VLS5 Memorias de semiconductores y estructuras de matrices [2] CE-VLS6 Circuitos de entrada / salida de chip CE-VLS7 Procesamiento y diseño CE-VLS8 Caracterización y funcionamiento del circuito CE-VLS9 Estructuras de circuitos alternativos / diseño de baja potencia CE-VLS10 Tecnologías de diseño semi-personalizadas CE-VLS11 Metodología de diseño ASIC
CE-DSC Estructuras discretas [33 horas] CE-DSC0 Historia y descripción general [1] CE-DSC1 Funciones, relaciones y conjuntos [6] CE-DSC2 Lógica básica [10] CE-DSC3 Técnicas de prueba [6] CE-DSC4 Fundamentos del conteo [4] CE-DSC5 Gráficos y árboles [4] CE-DSC6 Recursión [2]	**CE-PRS Probabilidad y Estadísticas** [33 horas] CE-PRS0 Historia y visión general [1] CE-PRS1 Probabilidad discreta [6] CE-PRS2 Probabilidad continua [6] CE-PRS3 Expectativa [4] CE-PRS4 Procesos estocásticos [6] CE-PRS5 Distribuciones de muestreo [4] CE-PRS6 Estimación [4] CE-PRS7 Pruebas de hipótesis [2] CE-PRS8 Correlación y regresión

(ACM/IEEE, 2004)

Tabla 3. El Cuerpo de Conocimientos de Ingeniería en Computación CE2016.

Ingeniería en Computación. Áreas y Unidades de Conocimiento	
CE-CAE Circuitos y Electrónica [50 horas] CE-CAE-1 Historia y visión general [1] CE-CAE-2 Herramientas, estándares y / o limitaciones de ingeniería relevantes [3] CE-CAE-3 Cantidades eléctricas y elementos básicos [4] CE-CAE-4 Circuitos eléctricos [11] CE-CAE-5 Materiales electrónicos, diodos y transistores bipolares [7] CE-CAE-6 Circuito transistor MOS, temporización y potencia [12] CE-CAE-7 Arquitectura de células de almacenamiento [3] CE-CAE-8 Familias de lógica de interconexión [3] CE-CAE-9 Amplificadores operacionales [3] CE-CAE-10 Diseño de circuitos de señales mixtas [3] CE-CAE-11 Parámetros de diseño y problemas CE-CAE-12 Modelos de circuitos y métodos de simulación	**CE-CAL Algoritmos de Computación** [30 horas] CE-CAL-1 Historia y visión general [1] CE-CAL-2 Herramientas relevantes, estándares y / o limitaciones de ingeniería [1] CE-CAL-3 Análisis algorítmico básico [4] CE-CAL-4 Estrategias algorítmicas [6] CE-CAL-5 Algoritmos clásicos para tareas comunes [3] CE-CAL-6 Análisis y diseño de algoritmos específicos de aplicación [6] CE-CAL-7 Algoritmos paralelos y multi-hilo [6] CE-CAL-8 Complejidad algorítmica [3] CE-CAL-9 Planificación de Algoritmos CE-CAL-10 Teoría básica de la computabilidad
CE-CAO Arquitectura y Organización de Computadoras [60 horas] CE-CAO-1 Historia y visión general [1] CE-CAO-2 Herramientas pertinentes, normas y / o limitaciones de ingeniería [1] CE-CAO-3 Arquitectura del conjunto de instrucciones [10] CE-CAO-4 Medición del rendimiento [3] CE-CAO-5 Aritmética computacional [3] CE-CAO-6 Organización del procesador [10] CE-CAO-7 Organización y arquitecturas del sistema de memoria [9] CE-CAO-8 Interfaz de entrada / salida y comunicación [7] CE-CAO-9 Subsistemas periféricos [7] CE-CAO-10 Arquitecturas Multi / varios-núcleos [5] CE-CAO-11 Arquitecturas de sistemas distribuidos [4]	**CE-DIG Diseño Digital** [50 horas] CE-DIG-1 Historia y visión general [1] CE-DIG-2 Herramientas relevantes, estándares y / o limitaciones de ingeniería [2] CE-DIG-3 Sistemas numéricos y codificación de datos [3] CE-DIG-4 Aplicaciones de álgebra booleana [3] CE-DIG-5 Circuitos lógicos básicos [6] CE-DIG-6 Diseño modular de circuitos combinacionales [8] CE-DIG-7 Diseño modular de circuitos secuenciales [9] CE-DIG-8 Diseño de control y ruta de datos [9] CE-DIG-9 Diseño con lógica programable [4] CE-DIG-10 Restricciones de diseño del sistema [5] CE-DIG-11 Modelos de fallas, pruebas y diseño para la prueba
CE-ESY Sistemas Incrustados [40 horas] CE-ESY-1 Historia y visión general [1] CE-ESY-2 Herramientas relevantes, estándares y / o limitaciones de Ingeniería [2] CE-ESY-3 Características de los sistemas incrustados [2] CE-ESY-4 Técnicas básicas de *software* para aplicaciones incrustadas [3] CE-ESY-5 Entrada y salida en paralelo [3] CE-ESY-6 Comunicación en serie asíncrona y síncrona [6] CE-ESY-7 Interrupciones periódicas, generación de formas de onda, medición del tiempo [3]	**CE-NWK Redes Computacionales** [20 horas] CE-NWK-1 Historia y visión general [1] CE-NWK-2 Herramientas relevantes, normas y / o limitaciones de Ingeniería [1] CE-NWK-3 Arquitectura de red [4] CE-NWK-4 Redes locales y de área amplia [4] CE-NWK-5 Redes inalámbricas y móviles [2] CE-NWK-6 Protocolos de red [3] CE-NWK-7 Aplicaciones de red [2] CE-NWK-8 Gestión de redes [3] CE-NWK-9 Comunicaciones de datos

CE-ESY-8 Adquisición de datos, control, sensores, actuadores [4] CE-ESY-9 Estrategias de implementación para sistemas incrustados complejos [7] CE-ESY-10 Técnicas para el funcionamiento de baja potencia [3] CE-ESY-11 Sistemas integrados móviles y en red [3] CE-ESY-12 Aspectos avanzados de entrada / salida [3] CE-ESY-13 Plataformas informáticas para sistemas incrustados	CE-NWK-10 Evaluación del desempeño CE-NWK-11Redes de sensores inalámbricos
CE-PPP Preparación para la práctica profesional [20 h] CE-PPP-1 Historia y visión general [1] CE-PPP-2 Herramientas pertinentes, normas y / o limitaciones de Ingeniería [1] CE-PPP-3 Estrategias de comunicación eficaces [2] CE-PPP-4 El equipo interdisciplinario se aproxima [1] CE-PPP-5 Marcos filosóficos y cuestiones culturales [2] CE-PPP-6 Soluciones de Ingeniería y efectos sociales [2] CE-PPP-7 Responsabilidades profesionales y éticas [3] CE-PPP-8 Propiedad intelectual y cuestiones jurídicas [3] CE-PPP-9 Temas contemporáneos [2] CE-PPP-10 Cuestiones empresariales y de gestión [3] CE-PPP-11 Intercambios en la práctica profesional	**CE-SEC Seguridad de la información** [20 horas] CE-SEC-1 Historia y visión general [2] CE-SEC-2 Herramientas pertinentes, normas y / o limitaciones de Ingeniería [2] CE-SEC-3 Seguridad e integridad de los datos [1] CE-SEC-4 Vulnerabilidades: factores técnicos y humanos [4] CE-SEC-5 Modelos de protección de recursos [1] CE-SEC-6 Criptografía de clave pública y secreta [3] CE-SEC-7 Códigos de autenticación de mensajes [1] CE-SEC-8 Seguridad de redes y web [3] CE-SEC-9 Autenticación [1] CE-SEC-10 Computación confiable [1] CE-SEC-11 Ataques de canal lateral [1]
CE-SGP Procesamiento de señales [30 horas] CE-SGP-1 Historia y visión general [1] CE-SGP-2 Herramientas, estándares y / o limitaciones de Ingeniería relevantes [3] CE-SGP-3 Convolución [3] CE-SGP-4 Análisis de transformación [5] CE-SGP-5 Respuesta de frecuencia [5] CE-SGP-6 Muestreo y aliasing [3] CE-SGP-7 Espectros digitales y transformadas discretas [6] CE-SGP-8 Diseño de filtro de respuesta de impulso finito e infinito [4] CE-SGP-9 Funciones de la ventana CE-SGP-10 Procesamiento multimedia CE-SGP-11 Teoría y aplicaciones de sistemas de control	**CE-SPE Sistemas e Ingeniería de Proyectos** [35 horas] CE-SPE-1 Historia y visión general [1] CE-SPE-2 Herramientas relevantes, estándares y / o limitaciones de Ingeniería [3] CE-SPE-3 Principios de gestión de proyectos [3] CE-SPE-4 Experiencia del usuario [6] CE-SPE-5 Riesgo, fiabilidad, seguridad y tolerancia a fallos [3] CE-SPE-6 Procesos de *hardware* y *software* [3] CE-SPE-7 Análisis y elicitación de requisitos [2] CE-SPE-8 Especificaciones del sistema [2] CE-SPE-9 Diseño y evaluación arquitectónica del sistema [4] CE-SPE-10 Diseño concurrente de *hardware* y *software* [3] CE-SPE-11 Integración, pruebas y validación de sistemas [3] CE-SPE-12 Mantenibilidad, sostenibilidad, manufacturabilidad [2]
CE-SRM **Gestión de Recursos de Sistemas** [20 horas] CE-SRM-1 Historia y visión general [1] CE-SRM-2 Herramientas pertinentes, normas y / o limitaciones de Ingeniería [1] CE-SRM-3 Gestión de recursos del sistema [8] CE-SRM-4 Diseño del sistema operativo en tiempo real [4] CE-SRM-5 Sistemas operativos para dispositivos móviles [3] CE-SRM-6 Soporte para procesamiento simultáneo [3] CE-SRM-7 Evaluación del rendimiento del sistema	**CE-SWD Diseño de *Software*** [45 horas] CE-SWD-1 Historia y visión general [1] CE-SWD-2 Herramientas relevantes, estándares y / o limitaciones de Ingeniería [3] CE-SWD-3 Programación de constructos y paradigmas [12] CE-SWD-4 Estrategias de resolución de problemas [5] CE-SWD-5 Estructuras de datos [5] CE-SWD-6 Recursión [3] CE-SWD-7 Diseño orientado a objetos [4]

CE-SRM-8 Soporte para virtualización	CE-SWD-8 Pruebas de *software* y calidad [5] CE-SWD-9 Modelado de datos [2] CE-SWD-10 Sistemas de base de datos [3] CE-SWD-11 Programación simultánea y concurrente [2] CE-SWD-12 Uso de interfaces de programación de aplicaciones CE-SWD-13 Extracción de datos CE-SWD-14 Visualización de datos

(ACM/IEEE, 2016)

Common themes

For the two curricula, within each area of knowledge, the first unit of learning is "History and General View". For the 2016 curriculum, the second one is "Relevant Tools, Standards and / or Engineering Restrictions". These two learning units provide the context for the rest of the knowledge area. The first learning unit also provides a context for learning outcomes, including important contributions and developments in the area. The practice of engineering requires the use of modern tools and contemporary standards that change over time. The scope of these learning units varies greatly depending on the area of knowledge and the goals of the program.

The importance of Bloom's taxonomy

Bloom's taxonomy allows you to classify learning objects into levels of complexity. In addition, it allows a global vision of the educational process, promoting a form of education with a holistic horizon. In this way, the taxonomy serves to plan and evaluate the levels of learning.

To gain a sense of what students should learn in each unit of learning, the emphasis on learning is important. The taxonomies of verbs such as "define" or "evaluate" are useful to describe the expected depth of learning. Levels of learning range from basic skills, such as reciting definitions, to advanced skills, such as participation in synthesis and evaluation. Therefore, learning outcomes provide a mechanism to describe not only relevant knowledge and practical skills, but also personal and transferable skills. Describe what we expect a student to do or know at the time of graduation.

Comparison in learning units

In the CE2016 writing, in its Appendix B, curricula of various institutions are shown. These are 3 institutions from the United States and 1 from the European Union (EUROPEAN SPACE OF HIGHER EDUCATION, s.f.). Table 4 shows a comparison of the number of learning units, number of semesters and average class hours per week compared to some Latin American universities. In the United States, the minimum and maximum number of learning units were placed, since it is the same number of semesters and the same average hours per class.

Tabla 4. Comparativa de Unidades de Aprendizaje. (Autoría propia)

PAÍS	NÚM. DE SEMESTRES	UNIDADES DE APRENDIZAJE	HORAS/CLASE PROMEDIO POR SEMANA
ESTADOS UNIDOS	8	36-39	3.33
EUROPA*	6	30	3
MÉXICO			
Universidad Nacional Autónoma de México[1]	10	52	4.65
Universidad Autónoma del Estado de México[2]	10	66	4.0
COLOMBIA			
Universidad Nacional de Colombia[3]	10	59	3.88
VENEZUELA			
Universidad Dr. Rafael Belloso Chacin[4]	12	65	3.5

(Autoría propia)

*Con prerrequisito de 2 semestres de Cálculo y Física

[1]http://www.ingenieria.unam.mx/programas_academicos/licenciatura/computacion_plan2016.php

[2]http://denms.uaemex.mx/exporientavirtual/wp-content/uploads/2015/01/Mapa_Computacion.pdf

[3]http://disi.unal.edu.co/dacursci/sistemasycomputacion/IngSistemasyComputacion2014ESTANDAR.pdf

[4]https://www.urbe.edu/estudios/pregrado/ingenieria/computacion.html

Conclusion

The two reports handle the characteristics of a computer engineer in much the same way, but there are significant changes in the areas of knowledge of CE2016 with respect to CE2004. That is, the basic core of CE2016 became more compact and with areas of knowledge different from CE2004.

Table 4 shows a comparison of the hours per week taught on average per unit of learning and the total number of learning units in the area of computer engineering among some universities in the United States, the European Union and Latin America. As a result, it is observed that almost twice as many learning units are taught in Latin American universities and, in the worst case scenario, the number of class hours per week is 50% higher than in the United States and the same. European Union.

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Rol de Contribución	Definición (solo poner nombre del autor)
Conceptualización	Joel Ayala de la Vega
Metodología	Joel Ayala de la Vega
Software	NO APLICA
Validación	NO APLICA
Análisis Formal	NO APLICA
Investigación	Joel Ayala de la Vega Apoyo Irene Aguilar Juárez
Recursos	NO APLICA
Curación de datos	NO APLICA
Escritura - Preparación del borrador original	Joel Ayala de la Vega Apoyo Irene Aguilar Juárez
Escritura - Revisión y edición	Joel Ayala de la Vega Igual Irene Aguilar Juárez
Visualización	Joel Ayala de la Vega
Supervisión	Joel Ayala de la Vega
Administración de Proyectos	NO APLICA
Adquisición de fondos	Joel Ayala de la Vega Igual Irene Aguilar Juárez