The constantly changing face of computing makes the education of new generations of computing professionals extremely challenging. It’s critical that professionals are provided a continuum of educational opportunities and academic training throughout their careers. In response to this need, the IEEE Computer Society’s (CS’s) Educational Activities Board merged with the Professional Activities Board to form the Professional and Educational Activities Board (PEAB) in 2015. This merger facilitated the development of the Guide to the Software Engineering Body of Knowledge (SWEBOK) and training in the SWEBOK knowledge areas, as well as coordination of IT curriculum development activities and the creation of a Guide to the Enterprise IT Body of Knowledge (EITBOK), which will be available in wiki form later this year. Moreover, the merger serves to strengthen the CS’s joint work with ACM.

ACM and the CS signed a Memorandum of Understanding in 2005 to formalize their efforts to define computing reference curricula. Previous informal collaborations produced curricula for computing (CC/1991), computer science (CS/2001), and software engineering (SE/2004). The CS also endorsed an information systems curriculum (IS/2002), which was created by ACM in concert with the Association for Information Systems (AIS) and the Association of Information Technology Professionals. 2005 also saw the joint publication of Computing Curricula 2005: The Overview Report (CC/2005), which described five notional areas as the basis for curriculum development: computer engineering,
computer science, information systems, information technology, and software engineering.

CC2005 traces the evolution of these five disciplines. Before the 1990s, computer science and electrical engineering (and computer engineering, to some degree) were viewed as being widely separated from the business use of computers in the enterprise. The explosion of computing in the 1990s made it abundantly clear that too much was going on to cram all this burgeoning knowledge into the existing divisions. There was a need to tease out separate disciplines to address software engineering and to acknowledge the emerging discipline of information technology and bring it into the computing fold.

This division into five distinct areas was based on a distribution of computing disciplines across a notional knowledge space, as shown in Figure 2.

UNDERGRADUATE CURRICULA
The notional areas described above that delineate the five disciplines somewhat overlap, which isn’t unexpected given that they’re all part of computing. What’s significant, however, is that they carve out spaces that are sufficiently different, delineating a set of undergraduate curricula that students can choose from.

Computer engineering
CE2004, the current computer engineering curriculum, will soon be replaced by CE2016, as the ACM/IEEE steering committee produced its interim report for review by the computing community in October 2015. Some of the knowledge areas have been restructured. Like its companion reference curricula, CE2016 describes knowledge areas that will lead to a computer engineering program’s desired learning outcomes. In addition, it discusses professionalism and the engineering projects’ effects on society.

CE2016’s knowledge areas include circuits and electronics, computing algorithms, computer architecture and organization, digital design, embedded systems, computer networks, professional practice, information security, strategies for emerging technologies, signal processing, systems and project engineering, systems resource management, and software design.

Computer science
A unique aspect of the current computer science curriculum (CS2013) is its inclusion of course exemplars from many diverse universities, which show different ways in which the curriculum recommendations can be implemented. The authors recognize that computer science programs should allow students to work across many disciplines because graduates go on to work in such diverse areas as mathematics, electrical engineering, psychology, statistics, fine arts, linguistics, and physical and life sciences.

CS2013 adds several new knowledge areas to those defined in its predecessors, reflecting the field’s tremendous growth in complexity. The new knowledge areas are information assurance and security, networking
and communication, platform-based development, parallel and distributed computing, software development fundamentals, and systems fundamentals.

**Software engineering**
The current software engineering curriculum (SE2014) includes a description of knowledge to be addressed in an undergraduate software engineering program's core, called the Software Engineering Education Knowledge (SEEK). SEEK covers the entire spectrum of content for the discipline: information, terminology, artifacts, data, roles, methods, models, procedures, techniques, practices, processes, and literature.

The 10 knowledge areas that make up SEEK are computing essentials, mathematical and engineering fundamentals, professional practice, software modeling and analysis, requirements analysis and specification, software design, software verification and validation, software process, software quality, and security.

**Information technology**
The current version of the information technology curriculum was issued in 2008 (IT2008), but a new edition will soon be available for review and is projected to be published in 2017. The task group responsible for this project established desired competencies for graduates.

This curriculum's focus mirrors the work that consumes enterprise IT professionals: integrating different technologies and integrating technologies into organizations. The required skill set includes user advocacy skills, the ability to address information assurance and security concerns, the ability to manage complexity through abstraction, extensive capabilities for problem solving across a range of integrated information and communication technologies, adaptability, outstanding interpersonal skills, high ethical standards, and professional responsibility.

**Information systems**
The information systems curriculum (IS2010), created by ACM and the AIS and endorsed by the CS, builds on the foundation established in the previous versions, providing guidance on the core curriculum recommended for information systems programs in universities and colleges worldwide.

As with the other four curricula, IS2010 specifies learning outcomes to be achieved via the program. In this case, the high-level capabilities to be developed are

- improving organizational processes;
- exploiting opportunities created by technology innovations;
- understanding and addressing information requirements;
- designing and managing enterprise architecture;
- identifying and evaluating solution and sourcing alternatives;
- securing data and infrastructure; and
- understanding, managing, and controlling IT risks.

**USEFULNESS OF CURRICULA**

Beyond their value as reference models for curriculum developers, these curricula contribute to the advancement of computing professionals in several ways. Most obviously, they help university and college-bound students understand the breadth of the different fields in computing. The knowledge areas defined for each curriculum allow students to select the curriculum that will best prepare them for a career in their area of interest.

The curricula can also help working professionals decide what further areas of computing they might want to focus on for professional development (online or otherwise). Managers can use the curricula to guide hiring practices by narrowing their search to candidates with specific degrees to fill skill gaps in their organizations. Nontechnical managers can use them to better understand the technical areas of expertise (competencies) they need in their organizations.

Just as important, the ongoing revisions to each curriculum assure that each remains viable as computing capabilities and their application to real-life problems rapidly evolve. From PEAB's perspective, the curricula help us determine which training areas we should focus on to advance practitioners' knowledge beyond the basics in particular specializations.

**ACCREDITATION OF COMPUTING PROGRAMS**

The Accreditation Board for Engineering and Technology (ABET) is the non-profit, nongovernmental organization that accredits higher-education computing programs. Its voluntary peer-review process is sought internationally as a stamp of approval that an institution's computing programs are capable of producing graduates fit to enter a global workforce.

CSAB (formerly known as the Computer Sciences Accreditation Board), a joint venture between ACM and the CS, is ABET's lead society for computer science, information systems, information technology, and software engineering, and a cooperating society for biological, computer, and information engineering technology. CSAB coordinates the volunteers who evaluate programs and ABET issues the accreditations. There are currently more than 350 accredited computing programs in the US and more than 30 outside the US, and these numbers continue to grow.

CSAB trains practicing professionals as program evaluators (PEVs) to perform on-site assessment activities. Volunteers are chosen from industry, government, and academia. CSAB and ABET are currently seeking PEVs in computer science, information systems, and IT (www.abet.org/network-of-experts/join-us). All PEVs are members of either ACM or the CS; academic PEVs must hold an associate professor or professor rank in a computing discipline or equivalent; and PEVs from industry must have at least five years of work experience, including experience in hiring or selecting recent graduates.
Just as computing and its associated skills evolve, the curricula designed for teaching those skills also evolve. Computing disciplines move both vertically (up) and horizontally (out). As computing disciplines create smarter, faster computing technologies (moving up the chain), the topics taught must also move up the chain, including new techniques for making future generations of computers smarter and faster, and new techniques for using and integrating these advanced technologies in ever more complex computing environments.

The more we know, the more we create, and the greater the number of specialties to be addressed. Areas such as cybersecurity and data science emerge and claim recognition as disciplines in their own right. We must do our best to organize these disciplines as coherent knowledge areas and introduce them to a new generation of computing professionals.

CHARLENE “CHUCK” WALRAD
is managing director of Davenport Consulting. Contact her at cwalrad@daven.com.