Launching Curricular Guidelines for Computer Engineering: CE2016

FIE Panel Presentation
John Impagliazzo
CE2016 Steering Committee Members

**ACM**

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3 Countries, 3 continents

**IEEE Computer Society**

Eric Durant (MSOE)
Herman Lam (U of Florida)
Robert Reese (Mississippi State)
Lorraine Herger (IBM Research)
Salient Features of CE2016

Eliminated “Topics”

BOK driven by learning outcomes
  • Inspired by ACM community college IT effort of 2014
  • Realization of ABET engineering student outcomes

Each knowledge area defined by “area scope”
  • Several broad statements
  • Aggregate of all knowledge area scopes establishes computer engineering as a discipline
CE2016 Conferences

SIGCSE Symposium
2012, Raleigh

Frontiers in Education (FIE)
2012, Seattle, WA
2013, Oklahoma City, OK
2014, Madrid, Spain
2015, El Paso, TX
2016, Erie, PA

Presentations
IEEE TALE 2014, Wellington, NZ
IEEE EduCon 2015, Tallinn, Estonia
ECEDHA Symposium: 2016 San Diego

Brazil
Systems Engineering, 2015

China
ChinaSoft: Chengdu, 2015 April
CCF: Tianjin, 2015 November
Schedule

2016 August 22
ACM Education Council provisionally endorsed the project

2016 October 14-17
CE2016 Steering Committee finalizes document

2016 November
Final Endorsement by ACM and IEEE Computer Society

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Eric Durant
Salient Features of CE2016

• Target computer engineers in mid-2020s and beyond
  • 2021: First graduates of programs based on CE2016

• Each Knowledge Area defined by Area Scope
  • Three to seven broad statements
  • Aggregate of all knowledge area scopes establishes computer engineering as a discipline

• Body of Knowledge is minimal
  • Insufficient for a durable computer engineering program
  • Allows creation of unique programs/objectives
CE2016 Report Structure

Contents
1. Introduction
2. Computer engineering as a discipline *(What is a CE?)*
3. The CE body of knowledge
4. Engineering practice and the CE curriculum
5. Professional practice
6. Curriculum implementation issues
7. Institutional challenges

Appendices
A. Body of knowledge details
B. Sample curricula
C. Computer engineering laboratories
D. Acknowledgements
CE2016 Body of Knowledge

• 16 “core” areas – common to all CE programs
  • 12 computing-related, 420 instructional hours
    • One “hour” equivalent to a traditional lecture hour
    • 420 hours about 1 year (¼) of a typical program
    • CE2004 had 16 core areas, same hours
  • 4 math-related, 120 instructional hours
    • CE2004 had 2 core areas, 66 hours
    • Programs will generally have more math content

• BOK structure
  • Knowledge area - disciplinary subfield
    • Area Scope – broad themes characterizing the area
    • Knowledge areas are not courses!
  • Knowledge unit - individual thematic module
    • Core learning outcomes
    • Elective learning outcomes
Major BOK Revisions (from 2004 to 2016)
Resulting from surveys/workshops examining CE2004

- **System on Chip (SoC)** instead of VLSI.
- **Field Programmable Gate Array (FPGA)** instead of Application Specific Integrated Circuit (ASIC)
- **Multicore** beyond parallel
- Increased emphasis on **embedded systems**
- **Security**, particularly for networked and embedded devices, is now its own KA
- **Mobile** and other power-aware systems
- **Software**: object-oriented design, modern development processes (e.g., agile), refactoring
- Increased emphasis on **computer system engineering**: requirements, verification, validation for systems (encompasses hardware and software engineering)
- **Tools and standards** for hardware and software development/design
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tr>
<td>CE-CAE</td>
<td>Circuits and Electronics</td>
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<tr>
<td>CE-CAL</td>
<td>Computing Algorithms</td>
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<tr>
<td>CE-CAO</td>
<td>Computer Architecture and Organization</td>
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<td>CE-DIG</td>
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<td>CE-ESY</td>
<td>Embedded Systems</td>
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<td>CE-SRM</td>
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<td>CE-SWD</td>
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<td>CE-ACF</td>
<td>Analysis of Continuous Functions</td>
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<td>CE-LAL</td>
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<tr>
<td>CE-PRS</td>
<td>Probability and Statistics</td>
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Totals:

- Core Hours: 420
- Totals: 120
Knowledge Unit Learning Outcomes

- Each KU learning outcome specifies degree to which knowledge/skills are expected to be learned
  - Emphasis on **degree of learning**
  - Based on Bloom’s taxonomy: knowledge, comprehension, application, analysis, synthesis, evaluation

- **Core learning outcomes** would *normally* be included in required elements of the curriculum
  - Programs may choose to allocate more than the minimum specified core hours to achieve desired learning levels

- **Elective learning outcomes** typically correspond to extended coverage
  - Coverage depends on program emphasis
  - May include other learning outcomes not in the BOK
Joseph Hughes
Courses and Curricula

- CE2016 Report defines a program in terms of:
  - Computer Engineering Body of Knowledge
    - Knowledge Areas and Knowledge Units (with *minimum* expected lecture hours)
    - Core learning outcomes
    - Elective Knowledge Units and outcomes (to be expanded by individual programs)
  - Other Curricular Elements
    - Mathematics and sciences
    - Design throughout the curriculum
    - Laboratory experience
    - Complementary skills (e.g., communications, teamwork)

- GOAL: Preparation for professional practice
Courses and Curricula

- Academic institutions typically define a program in terms of:
  - Courses and credit hours
  - Standardized units and structures
  - Institutional core or general education requirements
  - Delivery options

- Mapping from CE2016 model to institutional implementation
  - Core knowledge units to include or omit and time/credit allocation
  - Additional elective units (specified or student-selected)
  - Additional institutional requirements
Courses and Curricula

- Guidelines for making the mapping
  - Knowledge areas are NOT intended to define courses
  - Consider structural options; e.g., separate or integrated laboratories
  - Focus on program-specific goals and objectives
  - Opportunities for course innovations (content or structure)
  - Acknowledge institutional constraints

- Plan for future evolution and changes
  - Computer engineering is a rapidly changing discipline
  - Curricula tend to change slowly
Courses and Curricula

• Model curricula in the CE2016 report
  • Five examples reflecting wide range of choices and constraints
    • ECE, CS, EE/CS, China, Europe
  • Summary of credit hour allocation
  • Typical term-by-term schedule
  • Mapping of knowledge area outcomes to specific courses
  • Sample course descriptions

• Examples only – NOT prescriptive
The Engineering Accreditation Criteria have two parts:

- **General Criteria**
  - This includes criteria covering students, program educational objectives, student outcomes, continuous improvement, curriculum, faculty, facilities, and institutional support
  - These are not discipline-specific
  - They must be satisfied by ALL accredited engineering programs

- **Program Criteria**
  - Development of program criteria is the responsibility of the lead society for the discipline, in collaboration with any cooperating societies for that discipline
  - These impose additional constraints on the curriculum and the faculty that are specific to the discipline
Proposed Changes to the Criteria

• All of what is currently required by Criterion 3 [(a) – (k)] and Criterion 5 will continue to be required if the proposed revisions are implemented.

• In addition:
  • It will be clear that college-level mathematics is mathematics that requires a degree of mathematical sophistication at least equivalent to that of introductory calculus.
  • The nature of the “basic science” component of the curriculum will be clearer
  • Diversity and inclusion will be a factor to consider in team experiences
  • Aspects of project management associated with such tasks as establishing goals, planning tasks, and meeting deadlines will be included

• No change to computer engineering program criteria are currently under consideration by the EAC
CE2016 and the Engineering Accreditation Criteria

• APPM II.E.3.c. EAC
  • Programs accredited by EAC are those leading to the professional practice of engineering.

• Executive Summary of the CE2016 Document
  • These recommendations support the design of computer engineering curricula that will support the design of computer engineering curricula that will prepare graduates to function at entry-level positions in industry for continued career growth or to enter graduate programs for advanced study
  • They reflect input from industrial and educational institutions
  • The report is the result of a cooperative global effort of the professionals involved
Consistency with Engineering Accreditation Criteria

• General Criteria
  • Proposed revisions to Criterion 3 and Criterion 5 include all of the outcomes required by the “old” (a) – (k) but also include outcomes that are concerned with such issues as diversity and inclusion in team experiences and aspects of project management associated with such tasks as establishing goals, planning tasks, and meeting deadlines will be included

• Body of Knowledge
  • Specifies in the Knowledge Areas core topical content, mastery of which satisfies the relevant parts of the Program Criteria for Computer Engineering.
  • Specifies in CE-PPP and CE-SPE topical content related to professional practice, working in diverse environments, project management issues, and risk management.
Summary: CE2016 and the Engineering Accreditation Criteria

• CE2016 is entirely consistent with the intent and the letter of the currently applicable Criteria

• CE2016 goes further in its recommendations and is also entirely consistent with proposed revisions to the Engineering Accreditation Criteria

• In knowledge areas CE-PPP and CE-SPE, the recommendations also incorporate aspects of Washington Accord exemplars that have not previously been included in computer engineering body of knowledge recommendations
Russ Meier
Computer engineering is a discipline that embodies the science and technology of design, construction, implementation, and maintenance of software and hardware components of modern computing systems and computer-controlled equipment.

CE2016 is a body of computer engineering knowledge units organized into knowledge areas with learning outcomes.

Core units are mandatory knowledge units.

Supplementary units are knowledge units that add study value.
Practical Elements – Implementing CE2016

**CE2016 does not require**
- Specific class formats.
- Specific topic placement by year.
- Specific elective tracks.
- Specific capstone design formats

**CE2016 suggests and guides toward**
- **Diverse** instructional methods
- **Best practices** to cover content
- **Balanced** breadth and depth
- **Professional practice** motivated capstone design
Practical Elements – Implementing CE2016

Assess
- What knowledge units are present and which are missing?
- What core units are present and which are missing?
- What supplementary units might add value?

Evaluate
- Why change the curriculum?
- What is the return on investment?
- What is a reasonable implementation time frame?

Implement
- Choose curriculum style: freshman-first, second-year start, etc.
- Balance computer engineering content across available years.
- Form study units including theory, practice, and professional
Audience Participation
More About

ABET Accreditation
Engineering Accreditation Criteria

• The EC2000 General Criteria were developed in the mid-1990’s – that is 20 years ago
• Since its inception, Criterion 3 (Student Outcomes) and Criterion 5 (Curriculum) of the General Criteria have only seen minor modifications
  • Programs have been dealing with outcomes (a) – (k) and assessing the extent to which these outcomes are attained for a long time, and improvement is needed
    • Some of the (a) – (k) outcomes are highly interdependent
    • Programs have found a need to engage in duplicative work
    • Some of the (a) – (k) outcomes are broad and vague in scope
      • Programs have difficulty understanding how such terms as “knowledge of contemporary issues”, for example
    • Some of the (a) – (k) outcomes are framed using language that makes attainment difficult to assess
      • How is one to determine whether students understand their ethical and professional responsibilities
      • Some of the (a) – (k) outcomes are inconsistently interpreted by program evaluators

• The world has changed in 20 years -- constituents and literature reviews have indicated the need for the inclusion of project management tasks and risk and uncertainty.
After a lengthy period of deliberation in October 2015

• The Engineering Area Delegation approved proposed changes to Criterion 3 and Criterion 5 at first reading.

• These proposed changes were published for a one-year period of review and comment.

• The intent of the proposed changes is to clarify outcomes that historically programs had difficulty assessing, allow for more efficient assessment processes, emphasize applications in an engineering context, and add some elements of project management. Furthermore, the proposed changes align ABET criteria more closely to Washington Accord graduate attributes referencing project management and finance.
In July of 2016

• Based on comment received during the review and comment period, some modifications to the proposed revisions to Criterion 3 and Criterion 5 were framed and endorsed by the EAC.

• A motion to approve these the proposed changes (as modified) to Criterion 3 and criterion 5 at first reading is on the agenda of the Engineering Area Delegation.

• With the Engineering Area Delegation approval at the first reading, the EAC will seek formal review and comment by major constituent groups for one year.

• If all goes as anticipated, the review and comment period will be from 2016 until 2017.
Program Criteria for Computer Engineering

- There are currently no proposed changes to the computer engineering program criteria under consideration by the EAC.

PROGRAM CRITERIA FOR
ELECTRICAL, COMPUTER, COMMUNICATIONS, TELECOMMUNICATION(S)
AND SIMILARLY NAMED ENGINEERING PROGRAMS
Lead Society: Institute of Electrical and Electronics Engineers
Cooperating Society for Computer Engineering Programs: CSAB

These program criteria apply to engineering programs that include “electrical,” “electronic(s),” “computer,” “communication(s),” telecommunication(s), or similar modifiers in their titles.

1. Curriculum
The structure of the curriculum must provide both breadth and depth across the range of engineering topics implied by the title of the program.

The curriculum must include probability and statistics, including applications appropriate to the program name; mathematics through differential and integral calculus; sciences (defined as biological, chemical, or physical science); and engineering topics (including computing science) necessary to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components. The curriculum for programs containing the modifier “electrical,” “electronic(s),” “communication(s),” or “telecommunication(s)” in the title must include advanced mathematics, such as differential equations, linear algebra, complex variables, and discrete mathematics.

The curriculum for programs containing the modifier “computer” in the title must include discrete mathematics.

The curriculum for programs containing the modifier “communication(s)” or “telecommunication(s)” in the title must include topics in communication theory and systems.

The curriculum for programs containing the modifier “telecommunication(s)” must include design and operation of telecommunication networks for services such as voice, data, image, and video transport.
The CE2016 recommendations support development of programs that produce graduates who

- Possess the ability to design computers, computer-based systems and networks that include both hardware and software and their integration to solve novel engineering problems, subject to trade-offs involving a set of competing goals and constraints. In this context, “design” refers to a level of ability beyond “assembling” or “configuring” systems.

- Have a breadth of knowledge in mathematics and engineering sciences, associated with the broader scope of engineering and beyond that narrowly required for the field.

- Acquire and maintain a preparation for professional practice in engineering.
Knowledge Areas

- CE-CAE Circuits and Electronics
- CE-CAL Computing Algorithms
- CE-CAO Computer Architecture and Organization
- CE-DIG Digital Design
- CE-ESY Embedded Systems
- CE-NWK Computer Networks
- CE-PPP Preparation for Professional Practice
- CE-SEC Information Security
- CE-SGP Signal Processing
- CE-SPE Systems and Project Engineering
- CE-SRM Systems Resource Management
- CE-SWD Software Design
CE-PPP Preparation for Professional Practice
[20 core hours]

- CE-PPP-1  History and overview [1]
- CE-PPP-2  Relevant tools, standards, and/or engineering constraints [1]
- CE-PPP-3  Effective communication strategies [2]
- CE-PPP-4  Multidisciplinary team approaches [1]
- CE-PPP-5  Philosophical frameworks and cultural issues [2]
- CE-PPP-6  Engineering solutions and societal effects [2]
- CE-PPP-7  Professional and ethical responsibilities [3]
- CE-PPP-8  Intellectual property and legal issues [3]
- CE-PPP-9  Contemporary issues [2]
- CE-PPP-10 Business and management issues [3]
- CE-PPP-11 Tradeoffs in professional practice
CE-SPE Systems and Project Engineering
[35 core hours]

• CE-SPE-1 History and overview [1]
• CE-SPE-2 Relevant tools, standards and/or engineering constraints [3]
• CE-SPE-3 Project management principles [3]
• CE-SPE-4 User experience* [6]
• CE-SPE-5 Risk, dependability, safety and fault tolerance [3]
• CE-SPE-6 Hardware and software processes [3]
• CE-SPE-7 Requirements analysis and elicitation [2]
• CE-SPE-8 System specifications [2]
• CE-SPE-9 System architectural design and evaluation [4]
• CE-SPE-10 Concurrent hardware and software design [3]
• CE-SPE-11 System integration, testing and validation [3]
• CE-SPE-12 Maintainability, sustainability, manufacturability [2]