Establishing Computing Curricula: An Evolving Professional Endeavor

John Impagliazzo, Ph.D.

2017 July 3
Outline

Phase 1:
Computing Curricular History

Phase 2:
Computer Engineering Curriculum (CE2016)

Phase 3:
Information Technology Curriculum (IT2017)

Phase 4:
Computing Curricular Overview (CC2020)

Phase 5:
General Questions
Computing Curricula History

**ACM Two-Year (Technical) College “Mini” Reports**
Data Processing (ca. 1962)

**ACM Curriculum ’68**
Landmark, Turing Award, Mix of Math and Computing (1968)

**Information Systems Report**
Independent, Dan Cougar (1973)

**ACM Recommendations and Guidelines for Associate-Degree Programs in Computer Programming**
ACM Produced (1975)
Computing Curricula History (2)

**ACM Curriculum ’78**  
Real Birth of Computer Science, Promoted Early Programming (1978)

**ACM Curriculum Modifications**  

**ACM Information Systems Report**  
First Organizational IS report (1983)

**Program in Computer Science and Engineering**  
IEEE Computer Society (Cain, Langdon, Varanasi)  
“Birth” of Computer Engineering as a Discipline (1984)
Computing Curricula History (3)

DPMA(AITP) ‘90 Information Systems Curriculum
Information Systems (1990)

ACM/IEEE Curriculum ‘91
Spurred by the Denning 1987 Paper “Computing as a Discipline”
Introduced Knowledge Areas and Knowledge Units
Abandoned Courses, Tried to be “One Size Fits All”
Arranged to Produce Thousands of Possible Curricula
Publishers Balked at the Recommendations – What Books to Publish?
Computing Curricula History (4)

Pre-1990:

EE  CS  IS
Hardware  Software  Business

Post-1990:

EE  CE  SE  CS  IS  IT
Hardware  Software  Organizational Needs
Computing Curricula History (5)

**ACM Reports on Associate-Degree Programs**
Four Reports: CS, IS, CET, CSS, Other Disciplines (1993)
Very Popular, All Printed Copies Sold Out

**ACM/AIS/DPMA(AITP) IS Curriculum ‘97**
Known and Used Worldwide

**ACM/AIS/DPMA(AITP) IS Curriculum 2002 (IS2002)**
Update of IS’97 (1997)

**ACM Reports for Associate-Degree Programs**
Curricula Updates (1995-2002)
Computing Curricula History (6)

ACM/IEEE Computing Curriculum (CC/CS2001)
Really Computer Science (2001)


Not Based on the 1984 Model

First of its Kind (2005)
Computing Curricula History (7)
Structural Organization (ca. 2005)

CC2005
The Guide to Undergraduate Degree Programs in Computing

CS2001 (CC2001)
Computer Science Curriculum Report

IS 2002
Information Systems Curriculum Report

SE 2004
Software Engineering Curriculum Report

CE 2004
Computer Engineering Curriculum Report

IT200(8)
Information Technology Curriculum Report

Other Curriculum Reports as needed for emerging disciplines
Computing Visualized

<table>
<thead>
<tr>
<th>Organizational System Issues</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Technologies</td>
<td></td>
</tr>
<tr>
<td>Software Development</td>
<td></td>
</tr>
<tr>
<td>Systems Infrastructure</td>
<td></td>
</tr>
<tr>
<td>Computer Hardware and Architecture</td>
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</table>

<table>
<thead>
<tr>
<th>Theory Principles Innovation</th>
<th>DEVELOPMENT</th>
<th>Application Deployment Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Theoretical</td>
<td>More Applied</td>
<td></td>
</tr>
</tbody>
</table>
Computer Engineering Visual

- Organizational System Issues
- Application Technologies
- Software Development
- Systems Infrastructure
- Computer Hardware and Architecture

CE

Theory Principles Innovation

DEVELOPMENT

More Theoretical More Applied

Application Deployment Configuration
Computer Science Visual

- Organizational System Issues
- Application Technologies
- Software Development
- Systems Infrastructure
- Computer Hardware and Architecture

Theory Principles Innovation

DEVELOPMENT

More Theoretical
More Applied

Application Deployment Configuration

CS
Information Systems Visual

Organizational System Issues
Application Technologies
Software Development
Systems Infrastructure
Computer Hardware and Architecture

Theory Principles Innovation
DEVELOPMENT
More Theoretical
More Applied
Application Deployment Configuration

IS
Information Technology Visual

- Organizational System Issues
- Application Technologies
- Software Development
- Systems Infrastructure
- Computer Hardware and Architecture

IT

DEVELOPMENT

More Theoretical  More Applied

Theory Principles Innovation

Application Deployment Configuration
Software Engineering Visual
Computing Visualized

All Computing
Computing Curricula History (8)

ACM/AIS Master’s Information Systems Curriculum (IS2006)
First of its Kind (2006)

ACM Computer Science Curriculum Report (CS2008)
Minor Update of CS2001 (2008)

ACM/IEEE Information Technology Report (IT2008)
First of its Kind (2008)

ACM/AIS Information Systems Curriculum (IS2010)
Update of Earlier Undergraduate Curriculum (2010)
Computing Curricula History \(^{(9)}\)

**ACM/IEEE Computer Science Curriculum (CS2013)**
Used a Two-Tier Core of “Musts” and “Shoulds”
Many Exemplars of Existing Programs

Update of SE2004 (2014)
Some Improvement over SE2004

**ACM Two-Year College Information Technology Curriculum**
Update from 2001 Document (2014)
Very Avant Gard; Learning Outcomes Only
No Course Identified
Computing Curricula History

**ACM/IEEE Computer Engineering Curriculum (CE2016)**
Moderate Update of CE2004 Curriculum (2016)
Balanced Approach to Curriculum Reform
Excludes Topics

**ACM/AIS Information Systems Curriculum (IS2016)**
Update of Earlier 2006 Undergraduate Curriculum (2016)

**ACM/IEEE Information Technology Curriculum (IT2017)**
Update of Earlier 2008 Undergraduate Curriculum (2017)
Representatives from Five Countries, Four Continents
Based on competencies
Driven by industry, 25% representation
Focus on *performance*, not knowledge
Computing Curricula Future

ACM/IEEE/AIS Cybersecurity Curriculum
Planned for 2018 (??)

ACM/AmStatSociety/IEEE Data Science Curriculum
Planned for 2019 (??)

ACM/IEEE/Computing Curricula 2020
Update of CC2005 (2020)

?????????
(2020s)
Alguma pergunta?
ACM/IEEE
Computer Engineering Curricular Guidelines
[CE2016]

An Update to CE2004
CE2016 Team

ACM

John Impagliazzo (Chair)*
Hofstra University

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Victor Nelson*
Auburn University

Joseph Hughes*
Georgia Tech

Weidong Liu
Tsinghua University

Junlin Lu
Peking University

Andrew McGettrick*
University of Strathclyde

IEEE COMPUTER SOCIETY

Eric Durant
Milwaukee School of Engineering

Herman Lam
University of Florida

Robert Reese
Mississippi State University

Lorraine M. Herger
IBM Research

* Member of CE2004 Team
CE2016 Report Structure

Contents
Introduction
Computer Engineering as a Discipline
Computer Engineering Body of Knowledge
Engineering Practice and the CE curriculum
Professional Practice
Curriculum Implementation Issues
Institutional Adaptation

Appendices
CE Body of Knowledge
CE Sample Curricula
CE Laboratories
CE2016 – Body of Knowledge

Knowledge Areas

CE-CAE  Circuits and Electronics
CE-CAL  Computing Algorithms
CE-DIG  Digital Design
CE-NWK  Computer Networks
CE-SEC  Information Security
CE-SGP  Signal Processing
CE-SWD  Software Design

Knowledge Areas

CE-CAO  Computer Arch. and Organization
CE-CSE  Computing Systems Engineering
CE-ESY  Embedded Systems
CE-PFP  Professional Practice
CE-SET  Strategies for Emerging Technologies
CE-SRM  Systems Resource Management
New Content

- System on Chip (SoC) instead of VLSI
- Field Programmable Gate Array (FPGA) instead of Application Specific Integrated Circuit (ASIC)
- Multicore beyond parallel
- 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
- Requirements, verification, validation for systems (encompasses hardware and software)
- Tools for hardware and software development and design
- Emerging technologies
# CE KAs, Math, and Core Hours

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Core Hours</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE-CAE</td>
<td>Circuits and Electronics</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>CE-CAO</td>
<td>Computer Architecture and Organization</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>CE-CAL</td>
<td>Computing Algorithms</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>CE-CSE</td>
<td>Computing Systems Engineering</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>CE-DIG</td>
<td>Digital Design</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>CE-ESY</td>
<td>Embedded Systems</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>CE-NWK</td>
<td>Computer Networks</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>CE-PFP</td>
<td>Professional Practice</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>CE-SEC</td>
<td>Information Security</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>CE-SET</td>
<td>Strategies for Emerging Technologies</td>
<td>10</td>
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<tr>
<td>CE-SGP</td>
<td>Signal Processing</td>
<td>30</td>
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<tr>
<td>CE-SRM</td>
<td>Systems Resource Management</td>
<td>20</td>
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</tr>
<tr>
<td>CE-SWD</td>
<td>Software Design</td>
<td>40</td>
<td>420</td>
</tr>
<tr>
<td>CE-CAN</td>
<td>Analysis of Continuous Functions</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>CE-DSC</td>
<td>Discrete Structures</td>
<td>30</td>
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<tr>
<td>CE-LAL</td>
<td>Linear Algebra</td>
<td>20</td>
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</tr>
<tr>
<td>CE-PRS</td>
<td>Probability and Statistics</td>
<td>30</td>
<td>110</td>
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</table>

**Totals:**

- Core Hours: 530
ESY Knowledge Units

CE-ESY-1  History and overview [1]
CE-ESY-2  Relevant tools, standards, and/or engineering constraints [2]
CE-ESY-3  Characteristics of embedded systems [2]
CE-ESY-4  Basic software techniques for embedded applications [3]
CE-ESY-5  Parallel input and output [3]
CE-ESY-6  Asynchronous and synchronous serial communication [6]
CE-ESY-7  Periodic interrupts, waveform generation, time measurement [3]
CE-ESY-8  Data acquisition, control, sensors, actuators [4]
CE-ESY-9  Implementation strategies for complex embedded systems [7]
CE-ESY-10  Techniques for low-power operation [3]
CE-ESY-11  Mobile and networked embedded systems [3]
CE-ESY-12  Advanced I/O topics [3]
CE-ESY-13  Computing platforms for embedded systems
CE-ESY-14  Tradeoffs in embedded systems
### ESY Knowledge Units

<table>
<thead>
<tr>
<th>CE-ESY-1</th>
<th>History and overview [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE-ESY-2</td>
<td>Relevant tools, standards, and/or engineering constraints [2]</td>
</tr>
<tr>
<td>CE-ESY-3</td>
<td>Characteristics of embedded systems [2]</td>
</tr>
<tr>
<td>CE-ESY-4</td>
<td>Basic software techniques for embedded applications [3]</td>
</tr>
<tr>
<td>CE-ESY-5</td>
<td>Parallel input and output [3]</td>
</tr>
<tr>
<td>CE-ESY-6</td>
<td>Asynchronous and synchronous serial communication [6]</td>
</tr>
<tr>
<td>CE-ESY-7</td>
<td>Periodic interrupts, waveform generation, time measurement [3]</td>
</tr>
<tr>
<td>CE-ESY-8</td>
<td>Data acquisition, control, sensors, actuators [4]</td>
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<tr>
<td>CE-ESY-9</td>
<td>Implementation strategies for complex embedded systems [7]</td>
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<tr>
<td>CE-ESY-10</td>
<td>Techniques for low-power operation [3]</td>
</tr>
<tr>
<td>CE-ESY-11</td>
<td>Mobile and networked embedded systems [3]</td>
</tr>
<tr>
<td>CE-ESY-12</td>
<td>Advanced I/O topics [3]</td>
</tr>
<tr>
<td>CE-ESY-13</td>
<td>Computing platforms for embedded systems</td>
</tr>
<tr>
<td>CE-ESY-14</td>
<td>Tradeoffs in embedded systems</td>
</tr>
</tbody>
</table>
KU Example: ESY-5

ESY-5  Parallel input and output
Minimum core coverage time: 3 hours

Core Learning Outcomes:
- Describe the appropriateness of different I/O configurations (input, strong drive, weak pullup/pulldown, open-drain, tri-state) available in general purpose I/O (GPIO) for a given target application.
- Create programs that perform a sequence of input/output operations on one more GPIOs using a polled approach.
- Describe how interrupts are supported on the target embedded system(s).
- Create programs that perform a sequence of input/output operations on one more GPIOs using an interrupt-driven approach.
- Discuss mechanisms such as hardware and software FIFOs for buffering data streams.

Supplemental Learning Outcomes:
- Discuss Direct Memory Access (DMA) and describe how it is supported on the target embedded system.
- Create programs that perform a sequence of input/output operations using DMA.
# CE Laboratories

## Types of Computer Engineering Laboratories

*(Table 4.1)*

<table>
<thead>
<tr>
<th>Laboratory Type</th>
<th>Must</th>
<th>Should</th>
<th>Supplemental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuits and Electronics</td>
<td>●●●●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Architecture Design</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Digital Signal Processing</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Digital Logic and System Design</td>
<td>●●●●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Embedded Systems</td>
<td>●●●●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction to Engineering</td>
<td>●●●●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Networking</td>
<td></td>
<td>●●</td>
<td></td>
</tr>
<tr>
<td>Software Design</td>
<td></td>
<td>●●</td>
<td></td>
</tr>
<tr>
<td>Senior Project Design</td>
<td>●●●●</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Embedded Systems Laboratory

Typical Description: Experiments involving interfacing memory and peripheral devices to a microcomputer; design of software to control peripheral devices; integration of computer hardware and software for system control.

Typical Configuration:
- microcontroller development board/kit
- computer for hosting software tools
- integrated development environment for the selected microcontroller
- libraries of software modules to support selected peripheral devices
- powered breadboard for interfacing peripheral devices to the microcontroller
- oscilloscope
- logic analyzer
- multimeter
- triple output DC power supply

Vendors for this equipment in 2016 include ST Microelectronics, Digilent, Keil, Agilent, and others.

Typical Offering: Lower level; one two-hour laboratory experience per week.
Where to find CE2016?

Go to:

www.acm.org

Then click on:

Education

Then click on:

Curricula Recommendations

Then scroll to:

Computer Engineering
CE2016
Alguma pergunta?
ACM/IEEE
Information Technology
Curricular Guidelines

[IT2017]

An Update to IT2008
IT2017 Team

Executive Committee

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University of New Hampshire, USA

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Al Imam Islamic University, Saudi Arabia

John Impagliazzo
Hofstra University, USA

Barry Lunt*
Brigham Young University, USA

Ming Zhang
Peking University, China

Brenda Byers
Federation of Enterprise Architecture Organizations, Canada

William Newhouse
National Institute of Standards and Technology, USA

Bill Paterson
Mount Royal University, Canada

Svetlana Peltsverger
Kennesaw State University, USA

Cara Tang
Portland Community College, USA

Gerrit van der Veer
Vrije Universiteit, Netherlands

Barbara Viola
VioTech Solutions, USA

* Member of IT2008 Team
Contents
Introduction
The Information Technology Discipline
Preparing Contemporary IT Professionals
Competencies and Information Technology
Industry Perspectives on Information Technology
Information Technology Curricular Framework
Implementing the IT Curricular Framework
Institutional Adaptations

Appendices
Enterprise IT Skills Framework
Performances
Traditional Four-year IT Curricula Examples
Information Technology in Other Contexts
Competency in Words
The term competence refers to the performance standards associated with a profession or membership to a licensing organization.

Competency as an Image

Knowledge
Skills
Attitudes
## Industry Driven (2016 Data)

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

<table>
<thead>
<tr>
<th>Business Skills/Soft Skills</th>
<th>Needed at Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility</td>
<td>41%</td>
</tr>
<tr>
<td>Analytical skills</td>
<td>39%</td>
</tr>
<tr>
<td>Teamwork</td>
<td>37%</td>
</tr>
<tr>
<td>Customer service</td>
<td>34%</td>
</tr>
<tr>
<td>Innovation/Problem solving</td>
<td>33%</td>
</tr>
<tr>
<td>Project management</td>
<td>30%</td>
</tr>
<tr>
<td>Strong work ethic</td>
<td>29%</td>
</tr>
<tr>
<td>Motivation</td>
<td>28%</td>
</tr>
<tr>
<td>Business understanding</td>
<td>27%</td>
</tr>
<tr>
<td>Broad technology knowledge</td>
<td>27%</td>
</tr>
<tr>
<td>Verbal/written communication</td>
<td>22%</td>
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</table>
## IT2017 Curricular Framework

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

- IT Technical Component: 45 credits (37.5%)
- Other Component: 57 credits (47.5%)
- Science Component: 6 credits (5%)
- Mathematics Component: 12 credits (10%)
IT2017 Curricular Framework (3)
Where to find IT2017?

Go to:

it2017.acm.org

Status:

Temporary working website

Final version available 2017 November
Alguma pergunta?
ACM/IEEE
Computing Curricula Overview Report

[CC2020]

An Update to CC2005
CC2020 Project

Activities
- Consolidation of all computing curricular guidelines
- Modern update of CC2005
- Avant-garde document for the future of computing education

Operational Structure
- Supported primarily by ACM and IEEE Computer Society
- Task Force (currently 30 representatives)
- Currently all global regions represented
  - 14 countries
  - 6 continents
- Steering committee (up to 15 reps) subset of task force
- Industry Perspectives on Information Technology

Outcome
- “Stay tuned”
Obrigado!
Questões gerais?