Ontem, Hoje e Amanhã: Computer Engineering and Other Curricula

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Computing Curricula

Ontem
Where we were

Hoje
Where we are

Amanhã
Where we might be

Ontem: Computing Curricula

Institutionally Sponsored Curricula

Many Claims and "Firsts"

First computing graduate

First computing doctorate

First computing program

First computing degree

Ontem: Computing Curricula

Organizationally Sponsored (1)

ACM Two-Year College "Mini" Reports
Data Processing (ca. 1962)

ACM Curriculum '68
Mix of Math and Computing (1968)

Information Systems Report
Independent, Dan Cougar (1973)

ACM Curriculum '78
Real Birth of Computer Science (1978)

Ontem: Computing Curricula

Organizationally Sponsored (2)

ACM Curriculum Modifications
Programming First (1983-1984)
CS1, CS2, CS3, Discrete Structures

ACM Information Systems Report
First Organizational IS report (1983)

IEEE Program in Computer Science and Engineering
"Birth" of Computer Engineering as a Discipline (1984)

DPMA '90 Information Systems Curriculum
Information Systems (1990)

Ontem: Computing Curricula

Organizationally Sponsored (3)

ACM / IEEE Curriculum '91

First Joint Organizational Report (1991)
Spurred by the Denning 1987 "Computing as a Discipline" Paper
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?

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

A 'Tour de Force' Information Systems Curriculum (1997)
Known and Used Worldwide

Ontem: Computing Curricula

Organizationally Sponsored (4)

ACM / IEEE Computing Curriculum 2001

CC '91 was Too Innovative had Basically Failed

Became the Update to CC '91

Really Became a Report on Computer Science

Recognized the Need for Other Non-CS Discipline Reports

ACM / AIS / DPMA/AITP IS Curriculum 2002

Update of IS'97 (1997)

Other ACM Reports for Associate-Degree Programs

Curricula Updates (1995-2002)

Ontem: Computing Education Changed

Computing - a family of disciplines

- Pre-1990:
  - ***Computer Science*** on the technical side
  - ***Information Systems*** on the business side
- During the 1990s:
  - ***Computer Engineering*** became a strong discipline
  - ***Software Engineering*** sometimes thought as an area within CS and began its own identity
  - ***Information Technology*** programs was common worldwide but began emerging in the US in the 1990s

Ontem: Computing Degree Programs

Pre-1990:

EE	CS	IS
Hardware	**Software**	**Business**

Post-1990:

EE	CE	SE	CS	IS	IT

Ontem: Computing Degree Programs

Pre-1990:

EE	CS	IS
Hardware	**Software**	**Business**

Post-1990:

EE	CE	SE	CS	IS	IT

Hardware

Ontem: Computing Degree Programs

Pre-1990:

EE CS IS

Hardware **Software** **Business**

Post-1990:

EE CE SE CS IS IT

Software

Ontem: Computing Degree Programs

Pre-1990:

EE	CS	IS
Hardware	**Software**	**Business**

Post-1990:

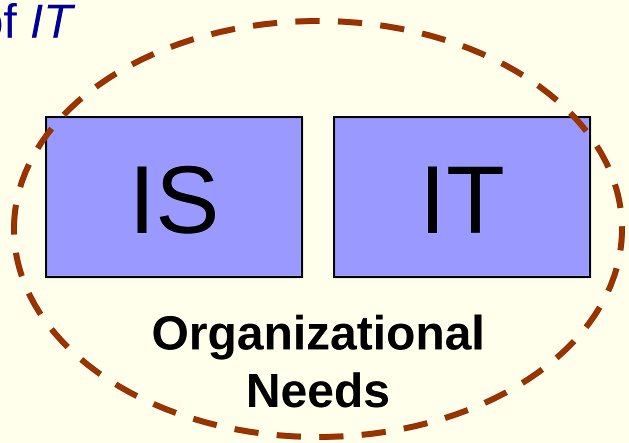
EE	CE	SE	CS	IS	IT

Organizational Needs

Ontem: Difference Between IT and IS

Both focus on using ***"Information Technology"***

- Information Systems programs:
  - Focus on the *Information* side of *IT*
- Information Technology programs:
  - Focus on the *Technology* side of *IT*



Ontem: Computing Degree Programs

Pre-1990:

EE CS IS

Hardware Software Business

Post-1990:

EE CE SE CS IS IT

Hardware Software Organizational Needs

Computing Curricula

2002

"Ontem" Ends

"Hoje" Begins

Hoje: Computing Curricula

Organizationally Sponsored (1)

ACM / IEEE Software Engineering Curriculum
First of Curriculum Report in the Field (2004)

ACM / IEEE Computer Engineering Curriculum
True CE-focused Report (2004)
Not Based on the 1984 IEEE Model

ACM / IEEE / AIS / Etc. Overview Report
First of its Kind (2005)

Hoje: 2005 Overview Report

Covers Five Undergraduate Degree Programs

Computer Engineering

Computer Science

Information Systems

Information Technology

Software Engineering

Hoje: CC2005 Task Force

Representatives of:

- ACM
- IEEE Computer Society
- Association for Information Systems
- ACM SIG Information Technology Education
- British Computer Society
- International Federation for Information Processing
- ABET and CSAB

Participants from Curricula Task Forces:

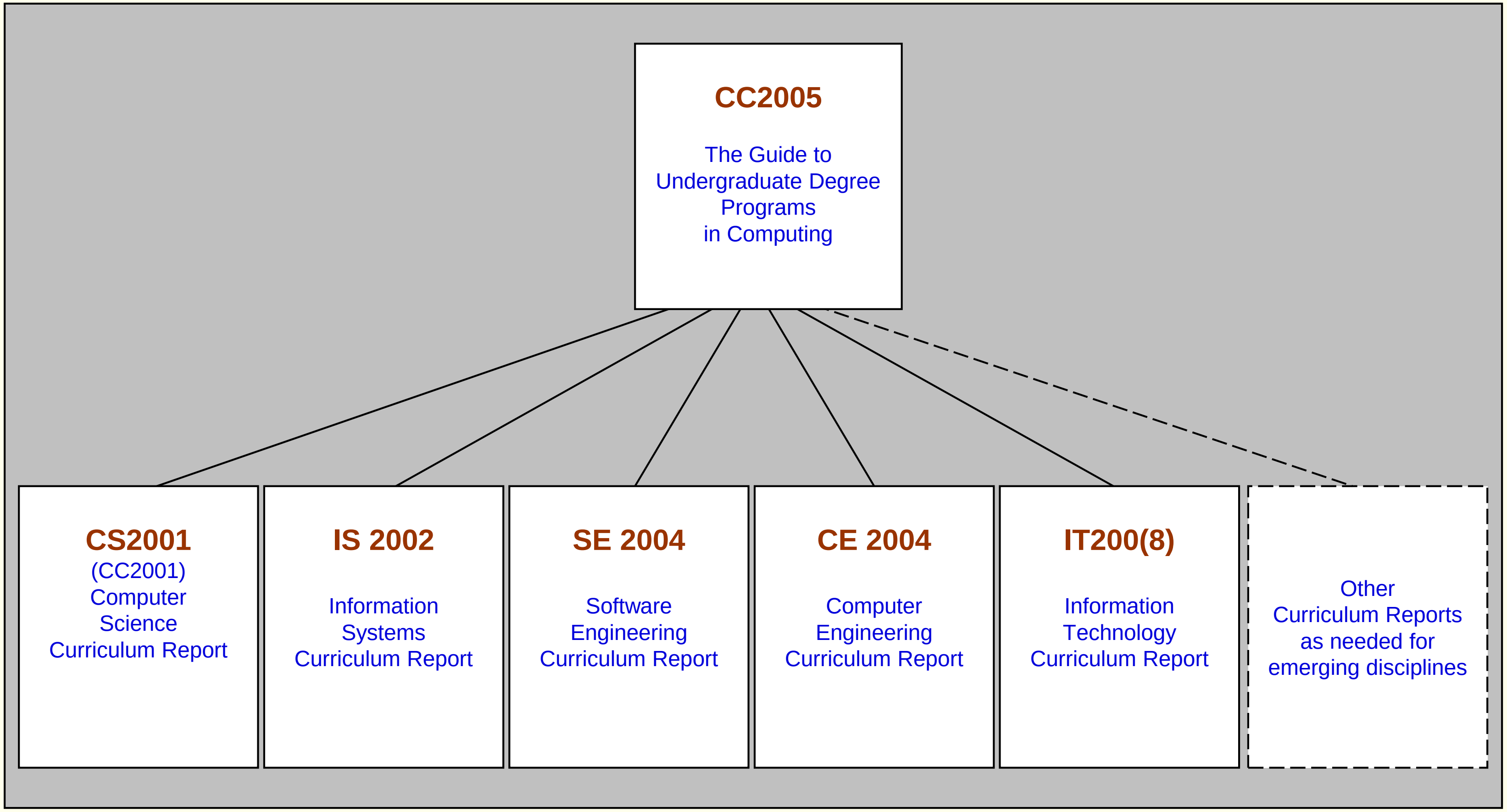
- CS2001 (formerly known as CC2001)
- IS2002
- IT200X (later became IT2008)
- CE2004
- SE2004

Hoje: Six Curricular Reports

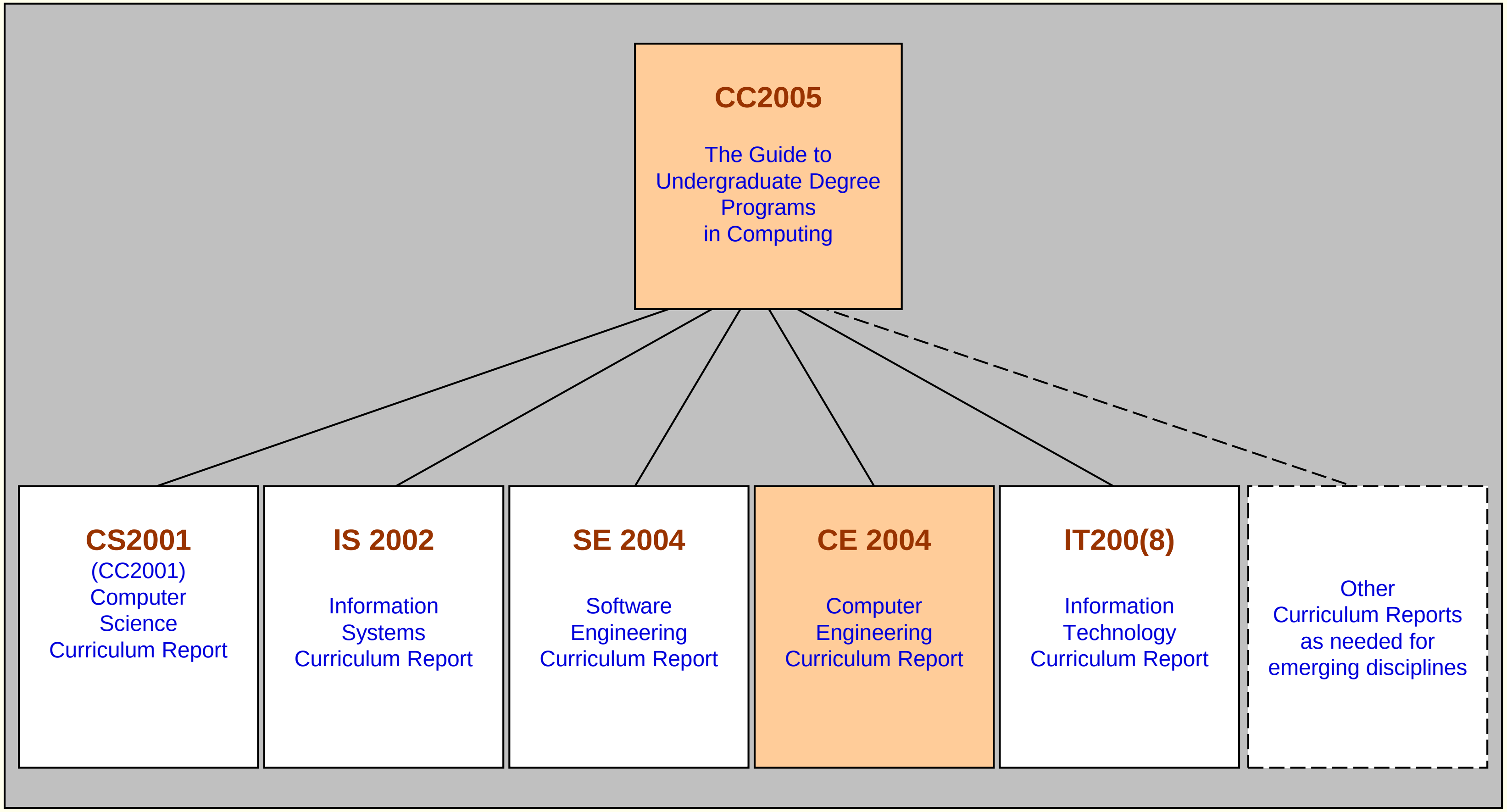
Computer Science	CS2001 (CC2001)
Information Systems	IS2002
Software Engineering	SE2004
Computer Engineering	CE2004
Information Technology	IT200x

- ***The Overview Report*** CC2005
  - Based on the *Body of Knowledge* from each of the above
  - Report on commonalities and differences
  - A users' guide to the computing disciplines
  - A larger project to create a map of computing

Hoje: Organizational Structure



Hoje: Organizational Structure



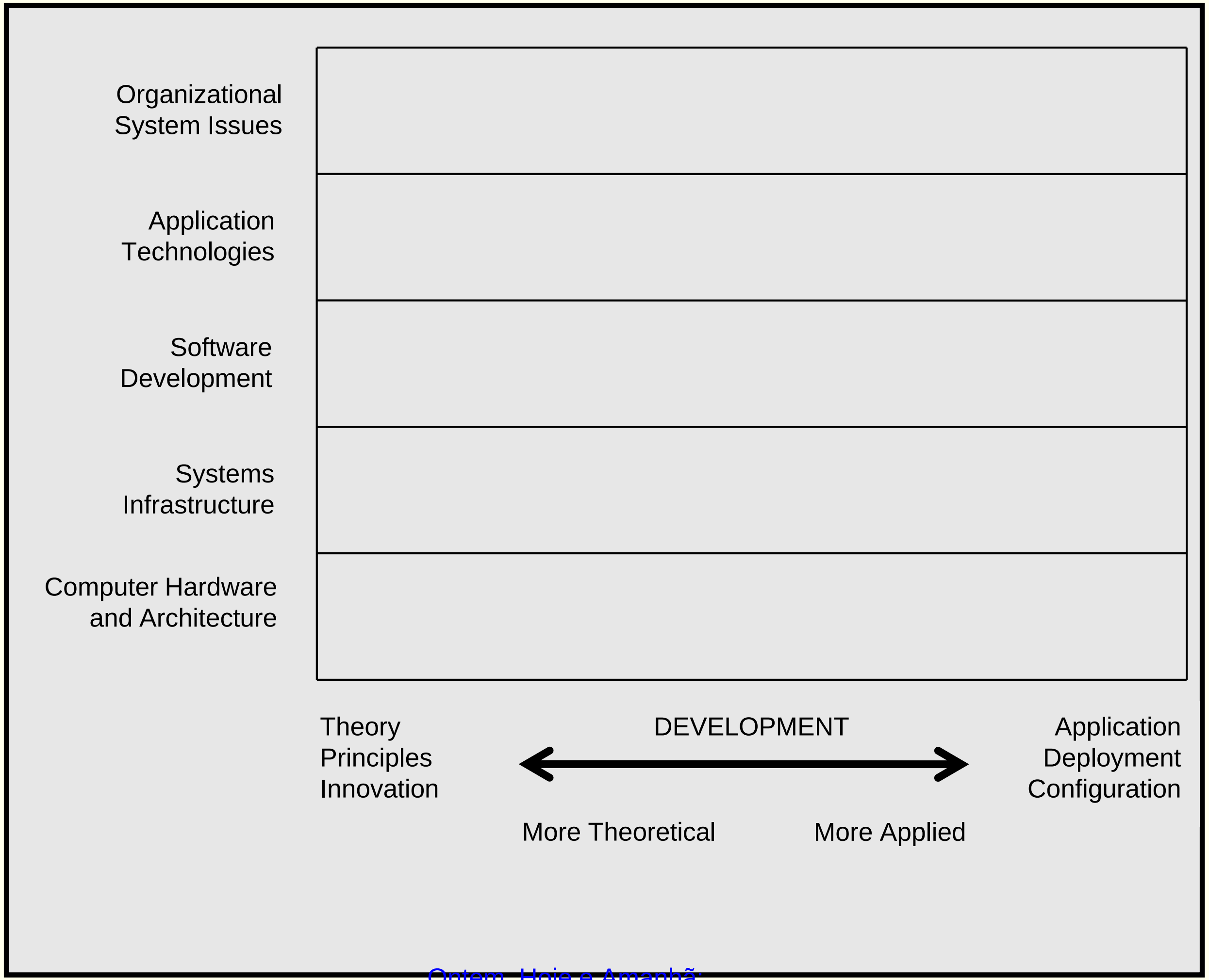
Hoje: Curricula Makeup (1)

- Computer Engineering
  - Design and construction of computers, and computer based systems (digital hardware/software systems)
  - Development of devices that have embedded systems
  - Integration of hardware and software
- Computer Science
  - Ranges from theoretical foundations to cutting-edge developments
  - Develop effective ways to solve computing problems
  - Designing and implementing software

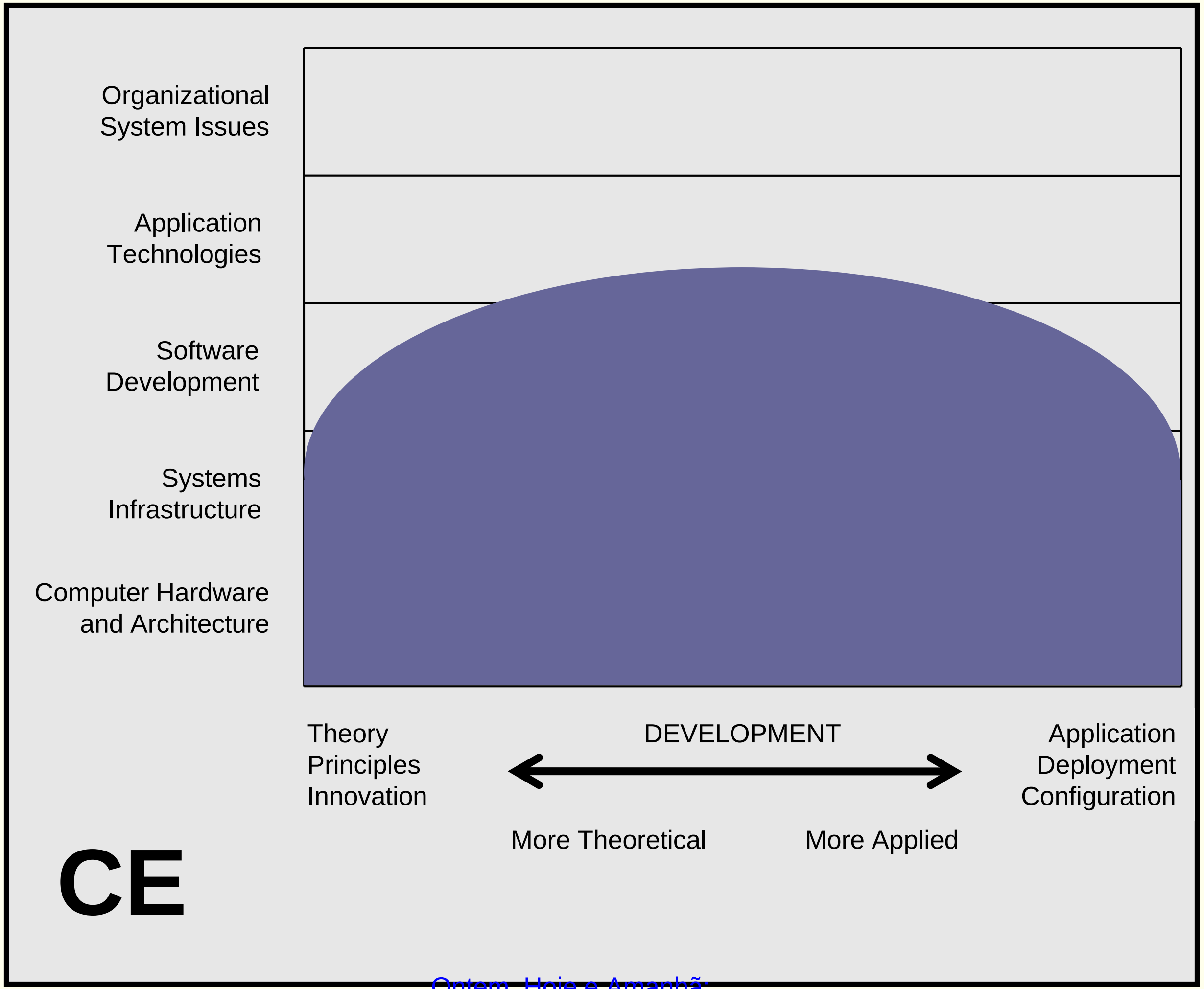
Hoje: Curricula Makeup (2)

- Information Systems
  - Satisfy informational needs of businesses and organizations and information provided by computer systems
  - Determines requirements and design of an organization's information systems
- Information Technology
  - Combination of knowledge and practical applications with hands-on expertise
  - Maintain an organization's information technology structure and install computer systems
- Software Engineering
  - Develop and maintaining large-scale, safety-critical, software systems
  - Integrates the science of computer science with engineering principles and practices

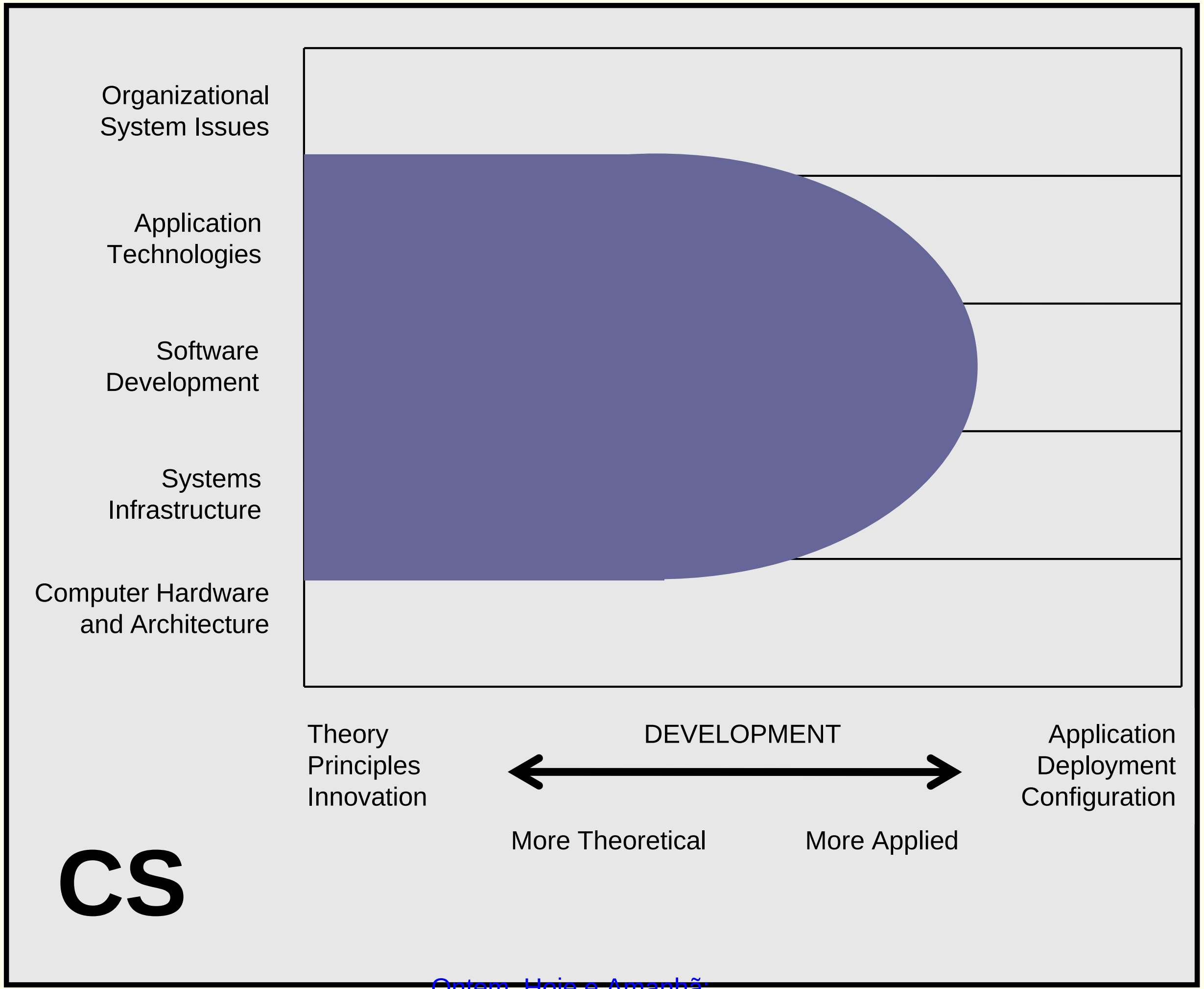
Hoje: Computing Visualized



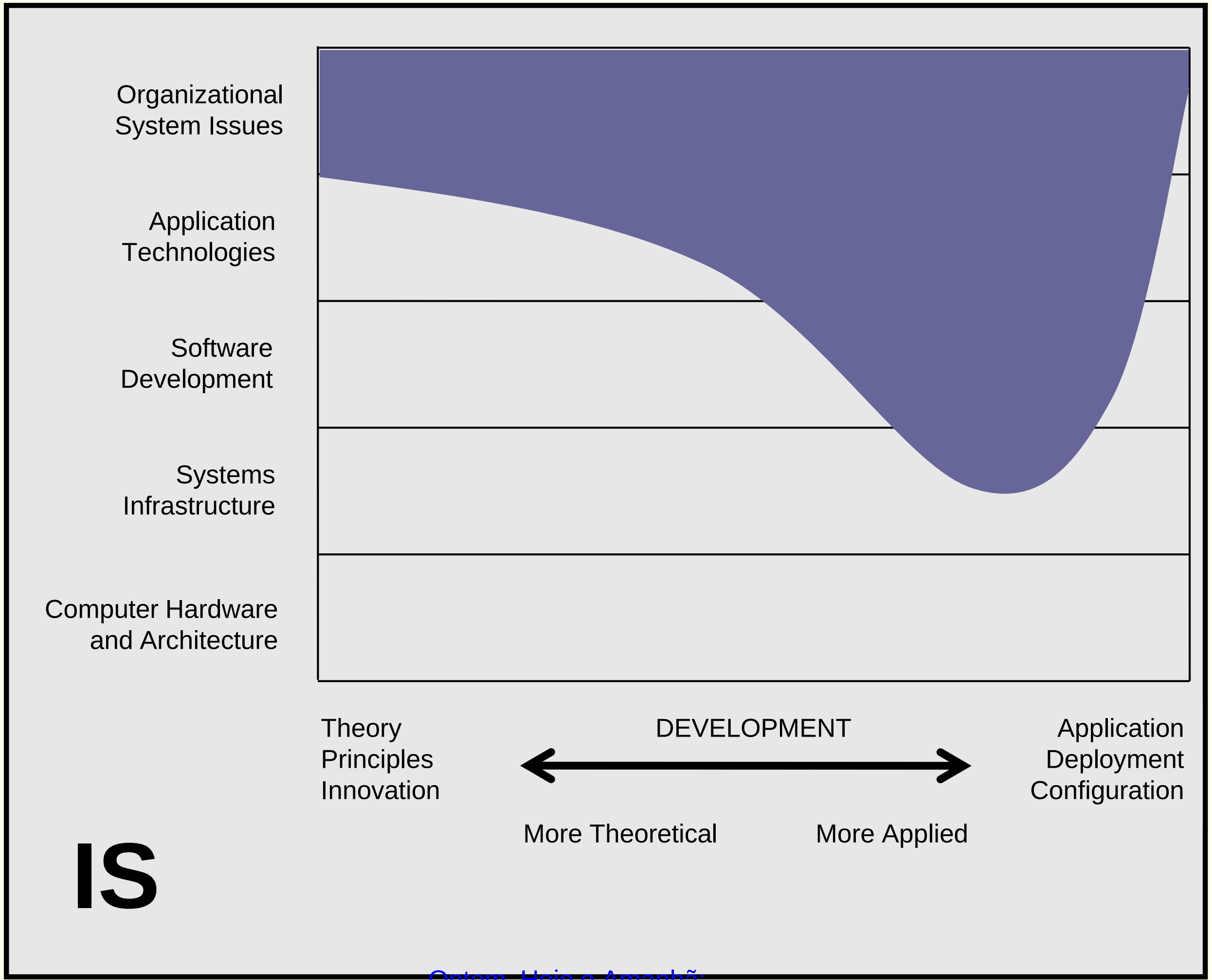
Hoje: Computer Engineering Visual



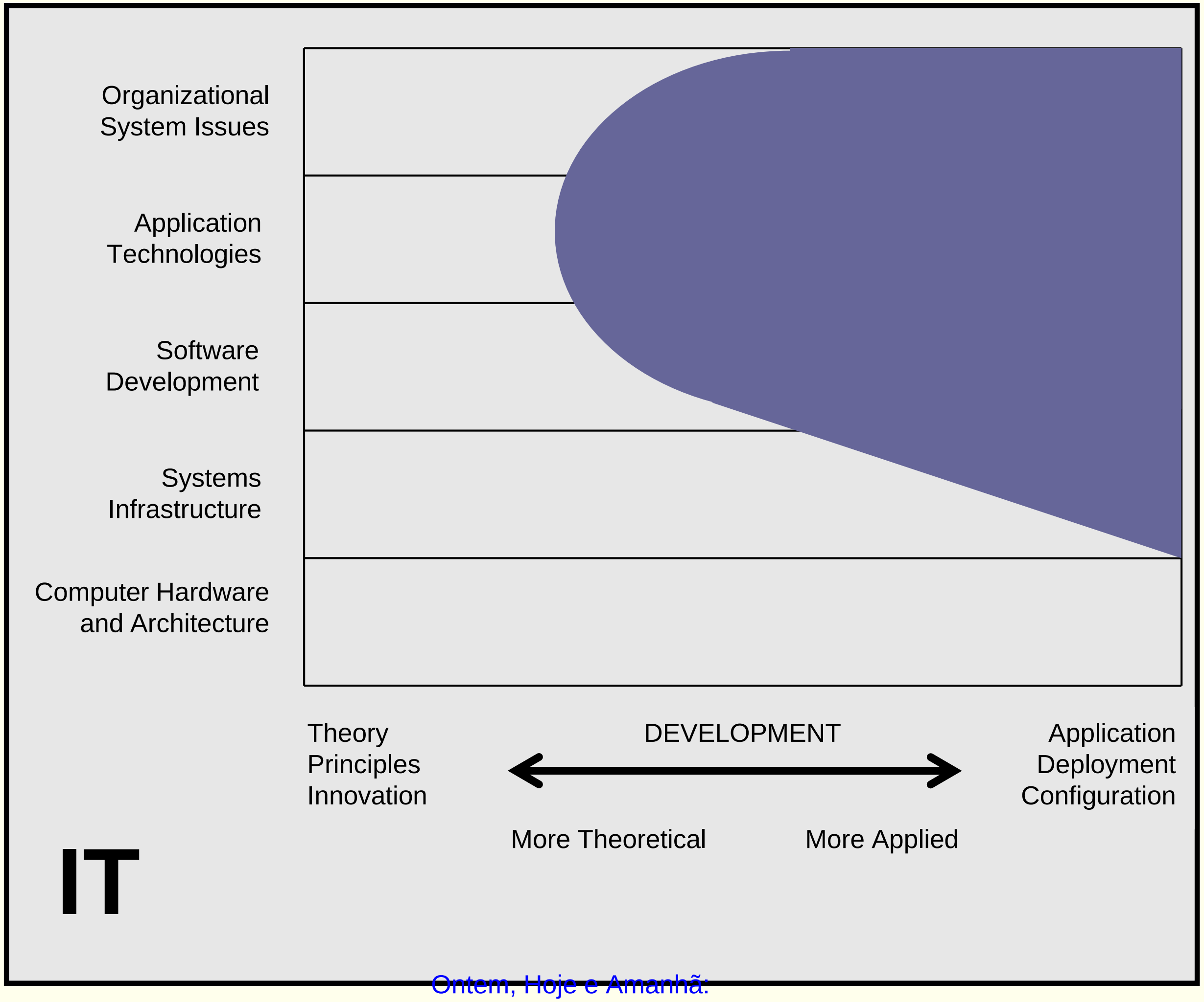
Hoje: Computer Science Visual



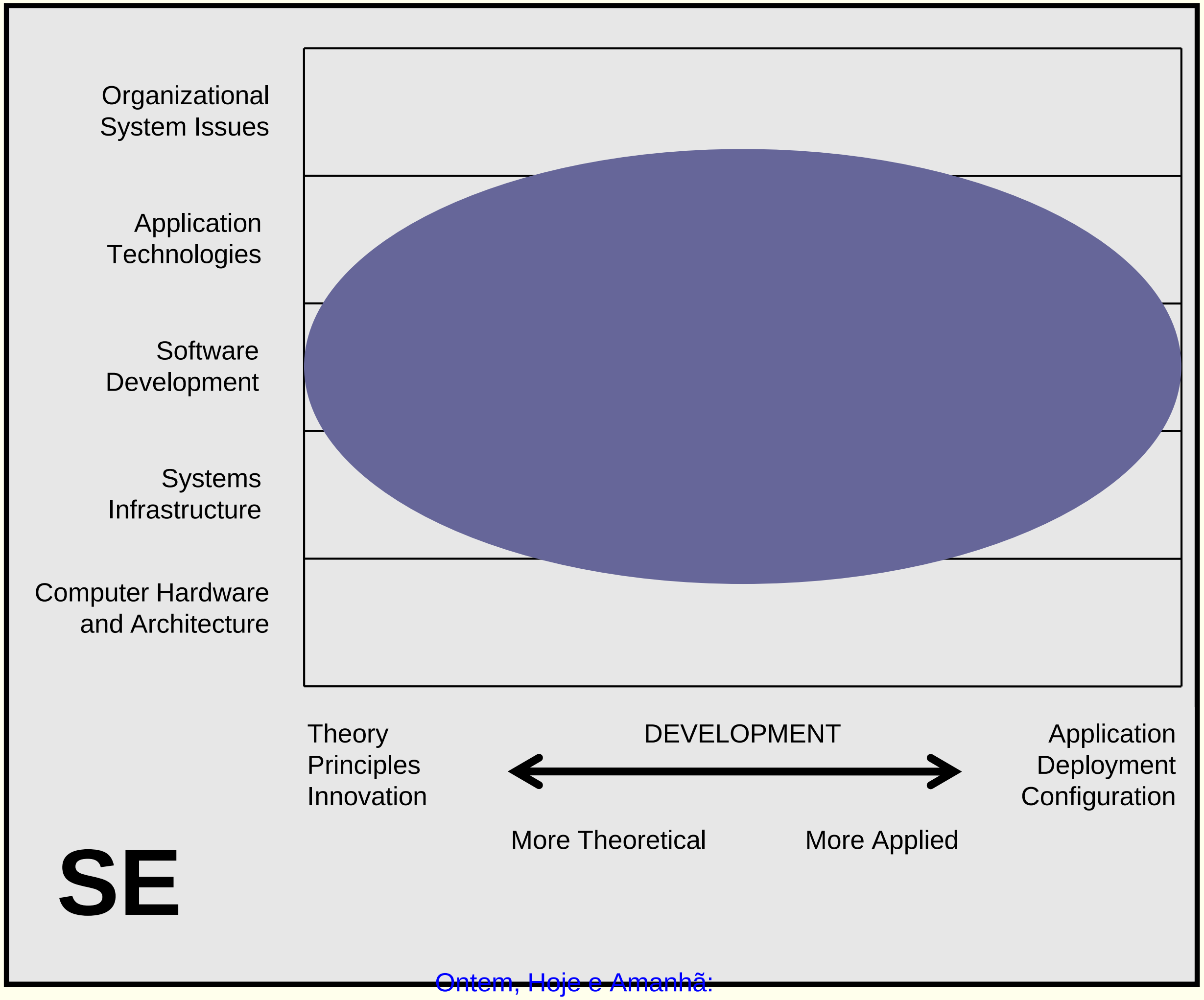
Hoje: Information Systems Visual



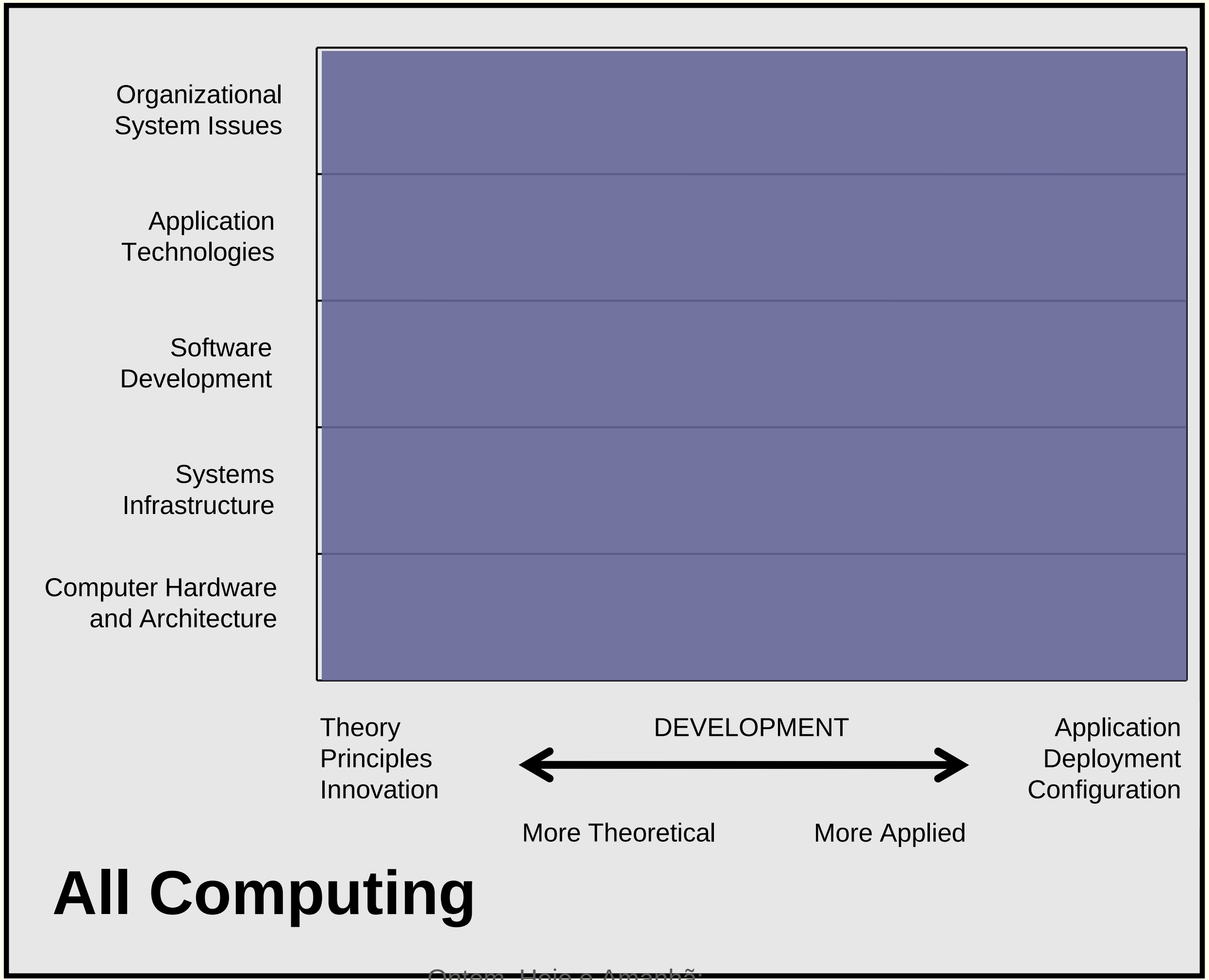
Hoje: Information Technology Visual



Hoje: Software Engineering Visual



Hoje: Computing Visualized



Hoje: Evolutionary Tendencies

- One may view the aforementioned curricula as five segregated packages
  - Some commonalities and some differences
  - Not sensitive to needs of business and industry
- Universities teach, research, and provide services
  - Often done in isolation
  - Not integrated as a whole
  - Universities educate, they do not train
- Massive changes in business and industry
  - Universities often remain stagnant
  - Universities must evolve and adapt to societal needs
  - Students seek jobs with difficulty

Hoje: Computing Curricula

Organizationally Sponsored (2)

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

ACM CS Curriculum Report
Minor Update of CS2001 (2008)

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

ACM / AIS Information Systems Curriculum
Update of Earlier Undergraduate Curriculum (2010)

Hoje: Outcome-Based Learning

- The primary focus of outcome-based learning has led to <u>assessment</u>
- Activities:
  - Establish a mission and vision
  - Identify stakeholders
  - Create measurable (key) performance indicators
  - Establish student learning outcomes
  - Align outcomes with educational practice
  - Develop a documented assessment process
  - Collect data and information for the process
  - Assess the learning outcomes periodically
  - Evaluate the program
  - Modify elements (performance indicators, learning outcomes, course details, etc.) as needed to improve the program
  - Repeat the ongoing process

Hoje: Program Goals/Objectives

Meaning

- Statements that describe the expected accomplishments of graduates during the first few years after graduation

Characteristics

- Formulated by constituencies of the program (not necessarily the faculty)
- Must be long-term (at least three years) and measurable
- Must show significant achievements of graduates from the program

Requirements

- Graduates should achieve at least one (not necessarily all) objective

Hoje: Student Learning Outcomes

Meaning

- Statements that describe what students are expected to know and be able to do by the time of graduation

Characteristics

- Formulated by the mission of the program
- Must be measurable
- Must document abilities of students upon graduation

Requirements

- Graduating students must achieve <u>all</u> program outcomes

Hoje: Assuring Quality

Question and Answer

- *Question*: How do we know we are producing a quality product (student graduates) in response to current student attitudes, university changes, and global dynamics?
- *Answer*: Assessment

Two Definitions

- **Assessment**: Processes that identify, collect, analyze, and report data that can be used to evaluate achievement
- **Evaluation**: Process of reviewing the results of data collection and analysis and making a determination of the value of findings and action(s) to be taken

Hoje: Types of Assessment

Formative vs. Summative

- **Formative** == Periodic (continuous) assessment
- Summative == Determined at end of project or course

Objective vs. Subjective

- **Objective** == Definitive responses to queries
- Subjective == Multiple (vague) responses to queries

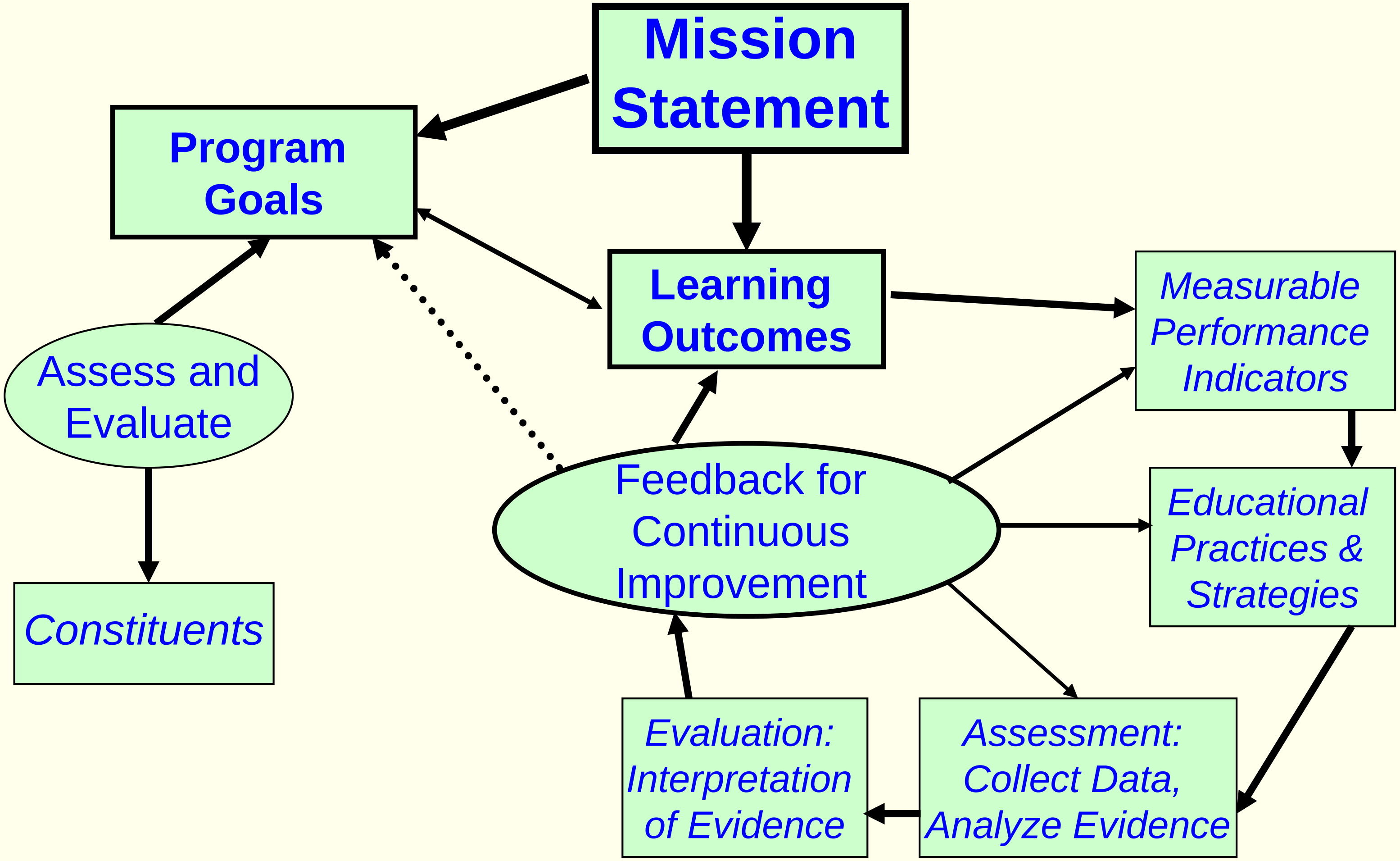
Criteria-based vs. Norm-based

- **Criteria-based** == Conforms to specific standards
- Norm-based == focused on average or accepted beliefs

Formal vs. Informal

- **Formal** == Quantitative and qualitative facts
- Informal == Casual overall judgments

Hoje: Graphical View



Hoje: Computing Curricula

2012

“Hoje” Ends

“Amanhã” Begins

Amanhã: Computing Curricula

Organizationally Sponsored (1)

ACM / IEEE Computer Science Curriculum

Update of CS2001/CS2008 Reports (2013)

Used a Two-Tier Core of “Musts” and “Shoulds”

Many Exemplars of Existing Programs

ACM / IEEE Software Engineering Curriculum

Update of SE2004 (2013-2014)

No Significant Improvement over SE2004

ACM Two-Year College Information Technology Curriculum

Update from 2001 Document (2014)

Very Avant Gard; Learning Outcomes Only

Amanhã: Computing Curricula

Organizationally Sponsored (2)

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

ACM Information Technology Curriculum
Update of Earlier 2008 Undergraduate Curriculum (2017)
Representatives from Four Countries with Great Diversity

ACM / AIS Information Systems Curriculum
Update of Earlier 2010 Undergraduate Curriculum (201x)

Amanhã: Computing Curricula

Organizationally Sponsored (2)

ACM / IEEE Computer Engineering Curriculum

Moderate Update of CE2004 Curriculum (2016)

Balanced Approach to Curriculum Reform

Amanhã: CE2016 Team

ACM

John Impagliazzo (Co-Chair)*
Hofstra University

Susan Conry
Clarkson University

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 (Co-Chair)
Milwaukee School of Engineering

Herman Lam
University of Florida

Robert Reese
Mississippi State University

Lorraine M. Herger
IBM Research

* Member of CE2004 Team

Amanhã: Team Activities

2011 (Hoje)

- February: Goals / plan constituent involvement
- March: Revise survey
- April: Finalize survey, pilot group, launch
- June: Analyze & discuss results
- July: Report to IEEE-CS EAB and ACM Education Board

2012

- March: SIGCSE Workshop
- Funding Issues
- October: FIE Special Session

2013

- BoK area research, research on major new topics
- October: FIE pre-conference workshop

2014

- April: Restructure BoK
- August: Review several KA drafts, settle on new format, draft core chapter
- October: FIE Workshop, Madrid
- December: IEEE TALE, New Zealand

Amanhã: CE2016 Report Structure

Contents

- Computer engineering as a discipline
- Principles
- Body of knowledge
- Engineering practice and the CE curriculum
- Professionalism
- Curriculum issues
- Institutional challenges

Appendices

- Body of knowledge
- Sample curricula

Amanhã: Some CE Definitions

Academic Core Hour (c.h.)

One academic “core” hour is the equivalent of a 50-minute lecture

Learning Outcome (LO)

Statements that describe what students are expected to know and be able to do by the time of graduation

Knowledge Unit (KU)

A kernel of information described by learning outcomes

Knowledge Area (KA)

A collection of knowledge units that describe a unified area of importance

Body of Knowledge (BoK)

A collection of knowledge areas containing a common theme

Amanhã: CE2004 – BoK – KAs

- CE-ALG Algorithms
- CE-CSE Computer Systems Engineering
- CE-DBS Database Systems
- CE-DSP Digital Signal Processing
- CE-ESY Embedded Systems
- CE-NWK Computer Networks
- CE-PRF Programming Fundamentals
- CE-SWE Software Engineering
- CE-CAO Computer Arch. and Organization
- CE-CSG Circuits and Signals
- CE-DIG Digital Logic
- CE-ELE Electronics
- CE-HCI Human-Computer Interaction
- CE-OPS Operating Systems
- CE-SPR Social and Professional Issues
- CE-VLS VLSI Design and Fabrication

Amanhã: CE2016 – BoK – KAs

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

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

Amanhã: CE2016 & CE2004

CE2016

- Knowledge Areas:13
- Knowledge Units
- Learning Outcomes
- No topic
- Each KA has a Scope
- CE Core: 420 Hours
- Math Core: 110 Hours
- Vision: Futuristic

CE2004

- Knowledge Areas: 16
- Knowledge Units
- Learning Outcomes
- Topics
- No KA Scope
- CE Core: 420 Hours
- Math Core: 66 Hours
- Vision: State-of-Art

Amanhã: Significant Revisions

- 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

Amanhã: Credits and Time

One Academic Hour

One hour is the equivalent to the time for a 50-minute lecture

One Academic Credit

Equivalent to 15 academic hours including exams
Consists of 14 academic hours excluding exams

One Academic Year

Equivalent to 30 academic credits == 450 academic hours
Excluding exams, **one academic year == 420 academic hours**

Four-Year Academic Program

Minimal four-year academic program is 120 credits == 1800 academic hours
Excluding exams, four-year academic program == 1680 academic hours

Amanhã: CE KAs, Math, and Core Hours

		Core Hours	Totals
CE-CAE	Circuits and Electronics	50	
CE-CAO	Computer Architecture and Organization	60	
CE-CAL	Computing Algorithms	30	
CE-CSE	Computing Systems Engineering	30	
CE-DIG	Digital Design	50	
CE-ESY	Embedded Systems	40	
CE-NWK	Computer Networks	20	
CE-PFP	Professional Practice	20	
CE-SEC	Information Security	20	
CE-SET	Strategies for Emerging Technologies	10	
CE-SGP	Signal Processing	30	
CE-SRM	Systems Resource Management	20	
CE-SWD	Software Design	40	***420***
CE-CAN	Analysis of Continuous Functions	30	
CE-DSC	Discrete Structures	30	
CE-LAL	Linear Algebra	20	
CE-PRS	Probability and Statistics	30	***110***
			530

Amanhã: KA Example: ESY

Area Scope

The units in this knowledge area collectively encompass the following:

- Purpose and role of embedded systems in computer engineering, along with important tradeoffs in such areas as power, performance, and cost
- Embedded systems programing, either in assembly language or a high level language or both, for typical embedded systems applications using modern tools and approaches for development and debugging
- Digital interfacing using both parallel and asynchronous/synchronous serial techniques incorporating typical on-chip modules as such as general purpose I/O, timers, and serial communication modules (i.e., UART, SPI, I2C, CAN, etc.)
- Analog interfacing using analog-to-digital convertors connected to common sensor elements and digital-to-analog converters connected to typical actuator elements
- Mobile and wireless embedded systems using both short-range (Bluetooth, 802.15.4) and long-range (cellular, Ethernet) in various interconnection architectures

Amanhã: ESY Knowledge Units

[40 Core Hours]

- 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

Amanhã: ESY Knowledge Units

[40 Core Hours]

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

Amanhã: 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.

Amanhã: CE2016 Future Timeline

2015*

- Spring: Steering Committee meets and produces next major draft and releases for comments
- June: ASEE ECE Panel Discussion
- Other conference events planned (e.g., ECEDHA, FIE)

2016*

- June: ASEE
- Potential final version

* Progression depends on feedback received

Obrigado!