SRI International

Center for Technology in Learning

SRI Education

Principled Assessment of Computational Thinking

Supporting Computer Science Teaching, Learning & Adoption Through Evidence-Centered Assessment

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2015 Korea Association of Information Education (KAIE) Winter Conference

Daegu, South Korea

January 8, 2015

Overview

- Introduction
- Assessment Arguments & Evidence-Centered Design
- Context: Principled Assessment of Computational Thinking (PACT)
  - Project Background
  - CT Domain Analysis
  - CT Domain Modeling
  - Example CT Assessment Task & Scoring
- Closing Comments

Overview

Slides and handouts will be available on the Publications page at:

http://pact.sri.com

A Bit About Me…

- Southern Oregon – West Coast US
- Cultural Anthropologist
- US Peach Corps Volunteer – Solomon Islands
- Education Research & Evaluation
- Father
- Mountain Biking

SRI International - Who We Are

A leading independent R&D organization

SRI headquarters, Menlo Park, CA

Sarnoff, Princeton, NJ

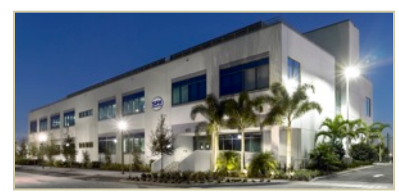
- Founded by Stanford in 1946
  - Based in Silicon Valley
  - Non-profit corporation
  - Independent in 1970
  - Acquired RCA Labs in 1987
- 2,300 staff members
  - 50% with advanced degrees
  - 20 locations worldwide
- $550M per year

SRI Harrisonburg, Virginia

SRI State College, Pennsylvania

SRI Tokyo, Japan

SRI Washington, D.C.

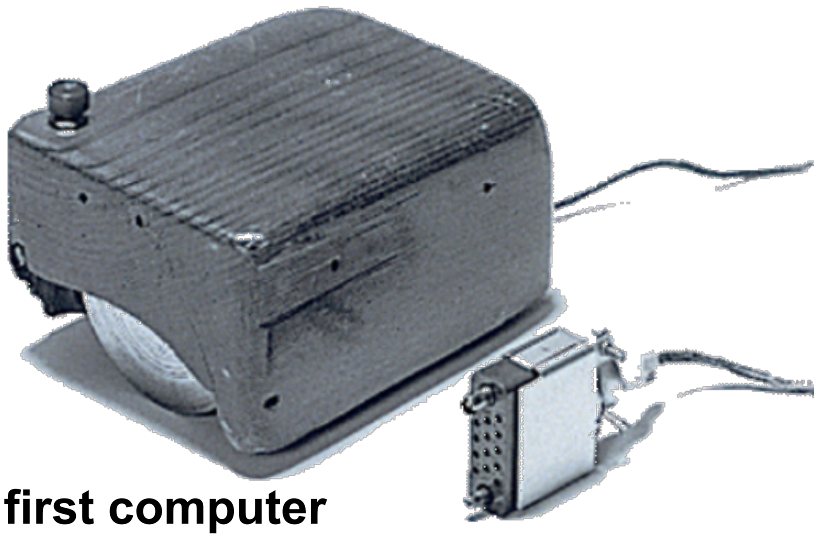


SRI St. Petersburg, Florida

SRI Invented the Mouse

National Medal of Technology

presented to Doug Englebart



The first computer mouse, circa 1964

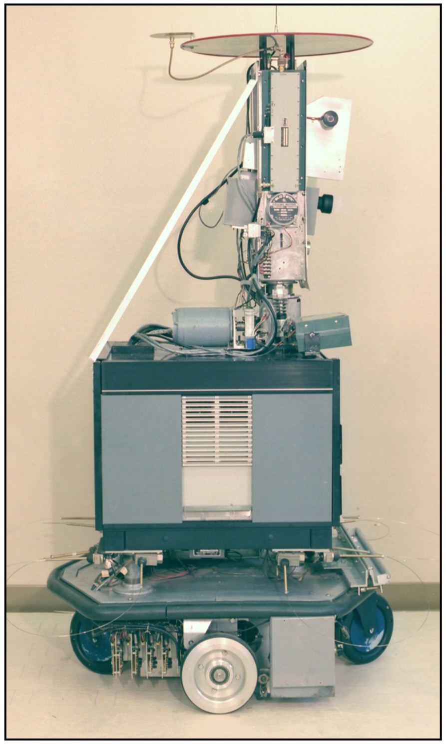
Internet Innovations

In 1976, this van initiated the first mobile, wireless communication between networks – from our parking lot.

.com
.gov
.org

SRI ran the Network Information Center (NIC) from its inception in 1970 to 1992 and created the designations .com, .gov, and .org.

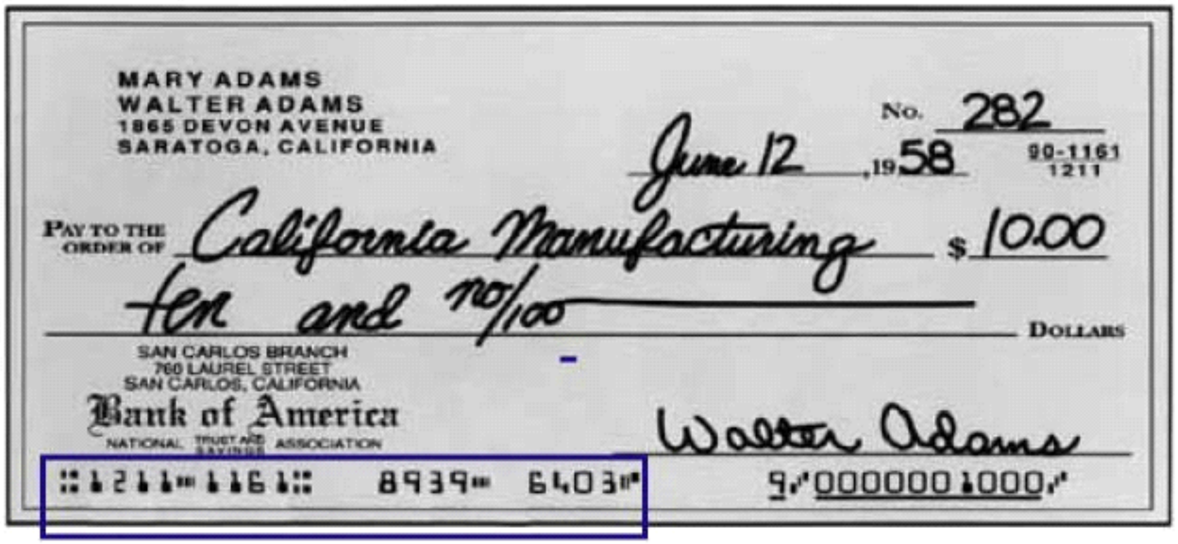
We're in the Robot Hall of Fame



Elected to the Robot Hall of Fame in 2004

Developed from 1966-1972, Shakey was the world's first mobile robot capable of reasoning about its surroundings.

You Know Those Little Numbers at the Bottom of Checks…



In 1956, SRI developed Magnetic Ink Character Reading (MICR) for account numbers that can be read by both machines and people

"The world's first successful use of computers in business operations was created by SRI for the world's largest bank... it saved the banking industry."

Bank of America

Siri was Born at SRI

"Siri is one of the top-10 new companies most likely to change the way we live and work."
MIT Technology Review 2009

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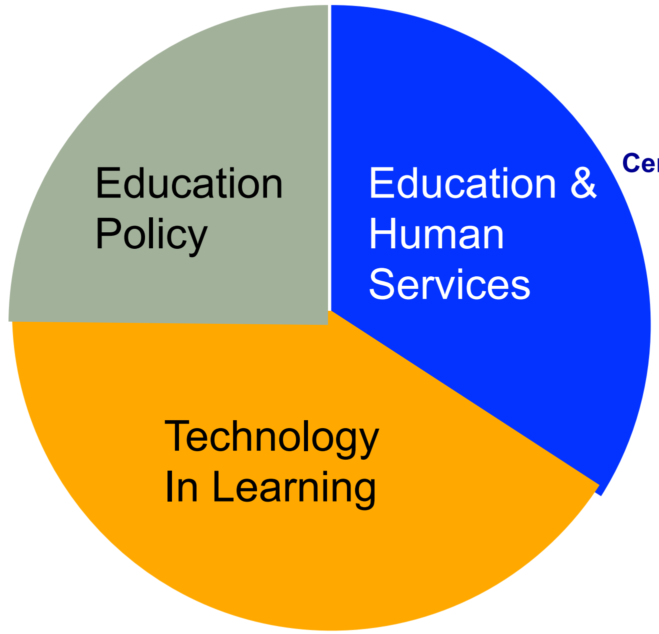
Denise Borders, Ed.D.
Vice President

Center for Education Policy
Dan Humphrey, Ph.D.
Director



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Center for Technology in Learning
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SRI Education
One Integrated Division and Strategy

Close to 200 researchers

…crossing disciplines in social sciences, content areas (math, science), policy analysis, assessment, program evaluation, and more

…working on the most complex and important challenges in education globally today

…combining rigorous research and evaluation with program design, product development and implementation

… bringing the expertise of the entire SRI organization to help students achieve.

Teaching Questions

- What are the main knowledge and skills students should learn?
- What classroom activities will help students learn the desired knowledge and skills?
- What evidence from classroom activities will help best determine how well students are learning the desired knowledge and skills?

Assessment Questions

- What complex of knowledge, skills, or other attributes should be assessed?
- What behaviors or performances should reveal those constructs?
- What tasks or situations should elicit those behaviors?

Assessment Questions

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Assessment Argument

In responding to the assessment questions we make a series of *inferences* about student knowledge and skills, and specify *warrants* for these inferences, and together these form what is called an Assessment Argument.

Operationalizing the Assessment Argument

What complex of knowledge, skills, or other attributes should be assessed?

What behaviors or performances should reveal those constructs?

What tasks or situations should elicit those behaviors?

How to we get from specifying an assessment argument to an assessment?

Operationalizing the Assessment Argument

What complex of knowledge, skills, or other attributes should be assessed?

What behaviors or performances should reveal those constructs?

What tasks or situations should elicit those behaviors?

Evidence-Centered Assessment Design (ECD)

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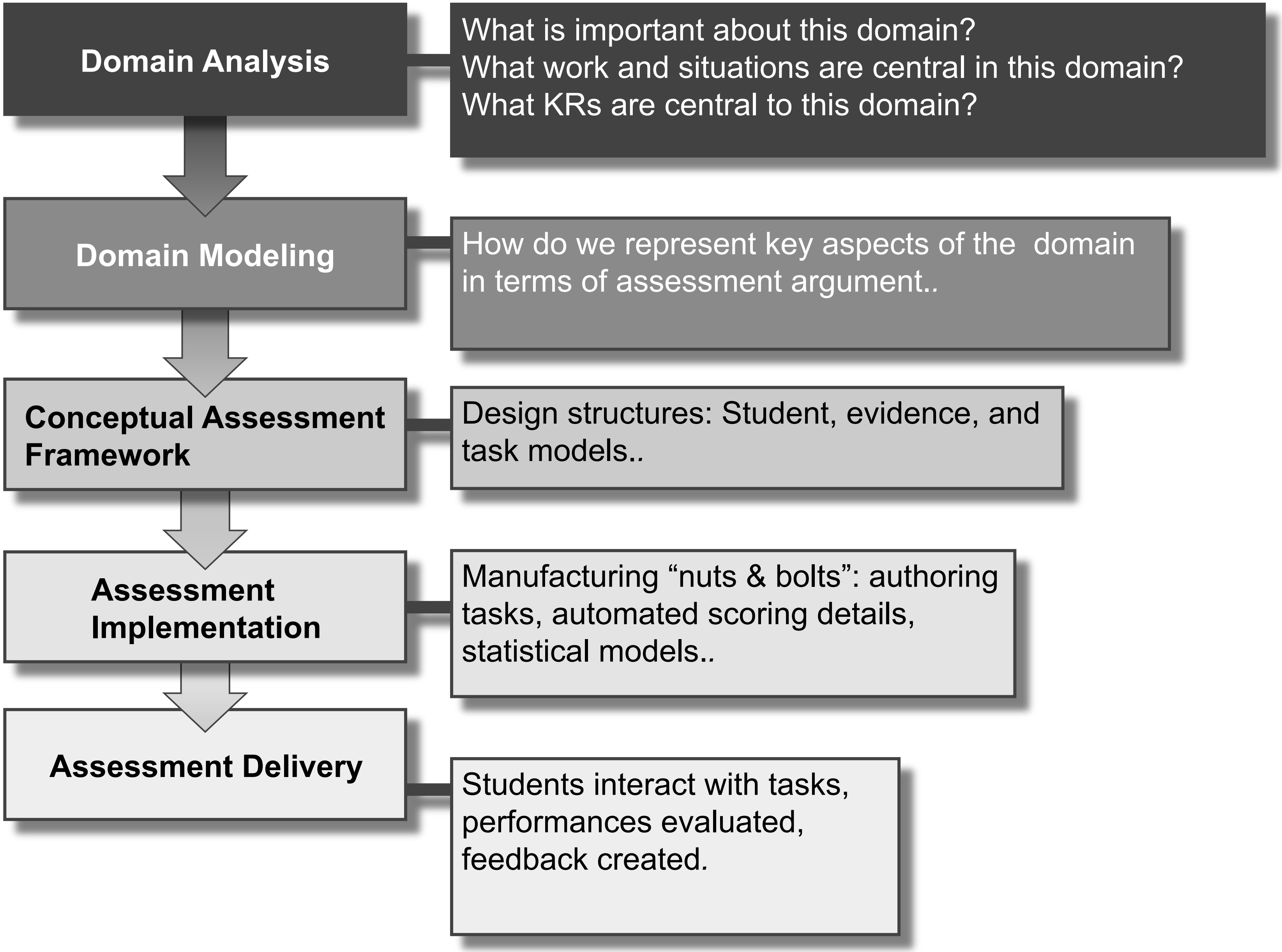
Evidence-Centered Assessment Design

- ECD is a framework for assessment design and development:
  - Views assessment as a process of gathering evidence to support an argument about what a student knows and can do
  - Provides a structure for an approach that incorporates validity evidence into the assessment design process
  - Documents what decisions have been made with regards to the assessment and the justification for those decisions



- From Mislevy & Riconscente, 2006

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Domain Analysis

What is important about this domain?
What work and situations are central in this domain?
What KRs are central to this domain?

- From Mislevy & Riconscente, 2006

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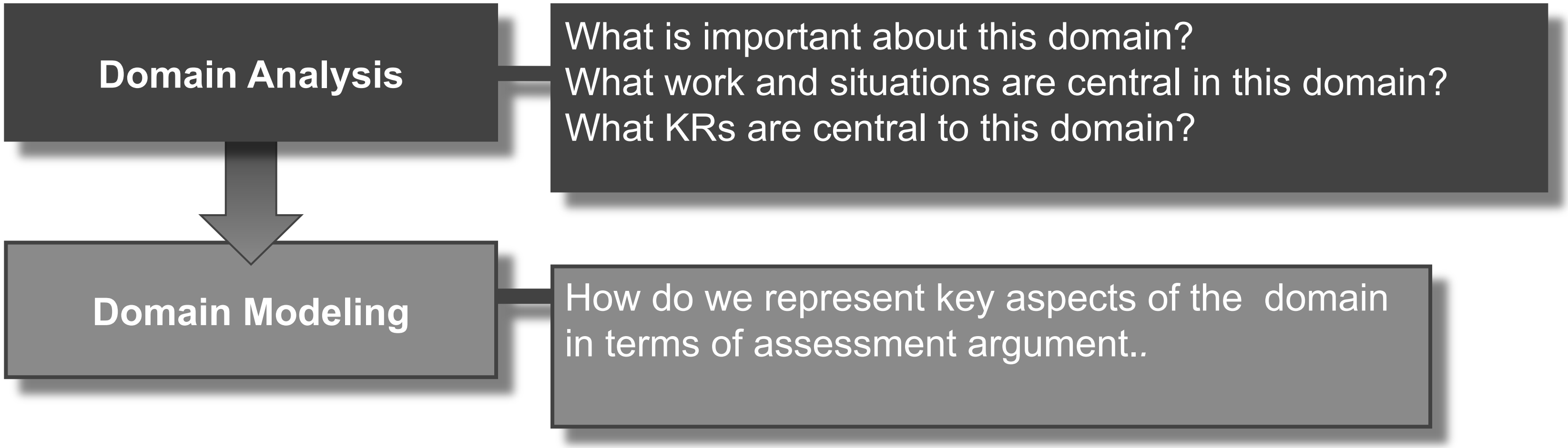
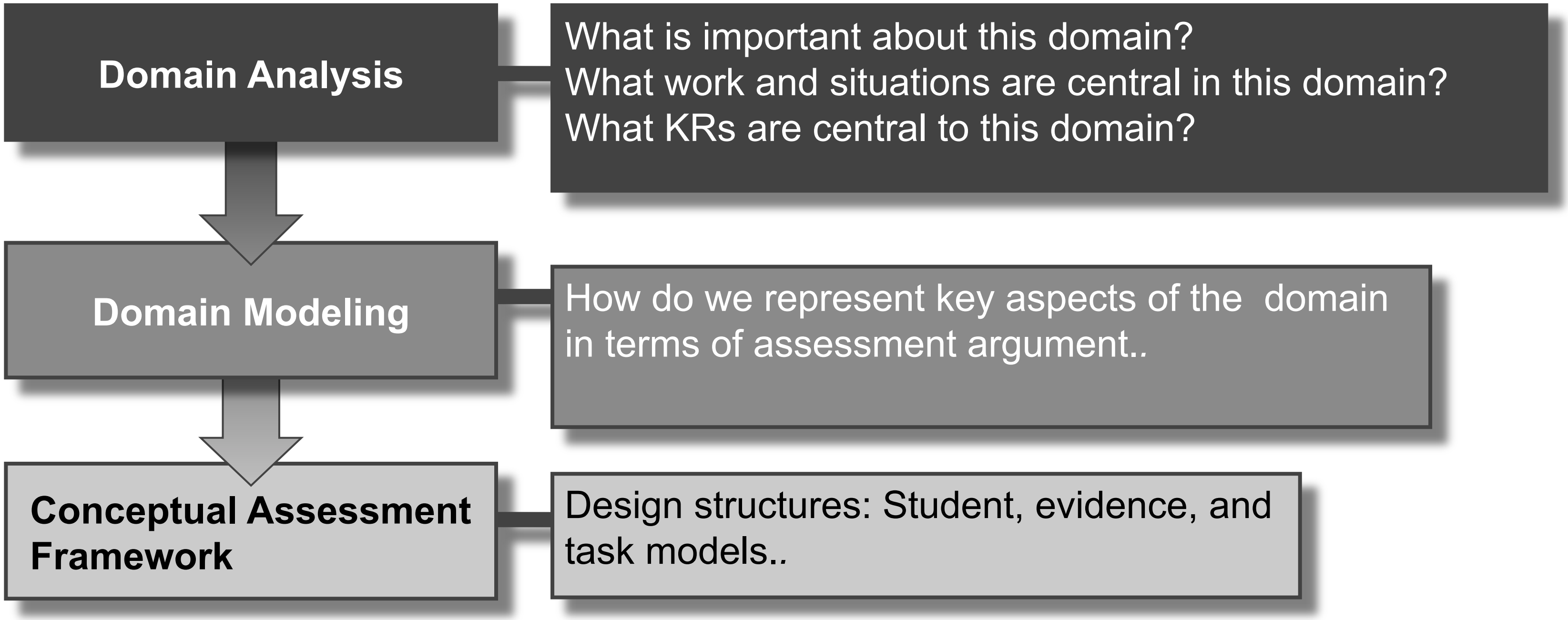


- From Mislevy & Riconscente, 2006



- From Mislevy & Riconscente, 2006

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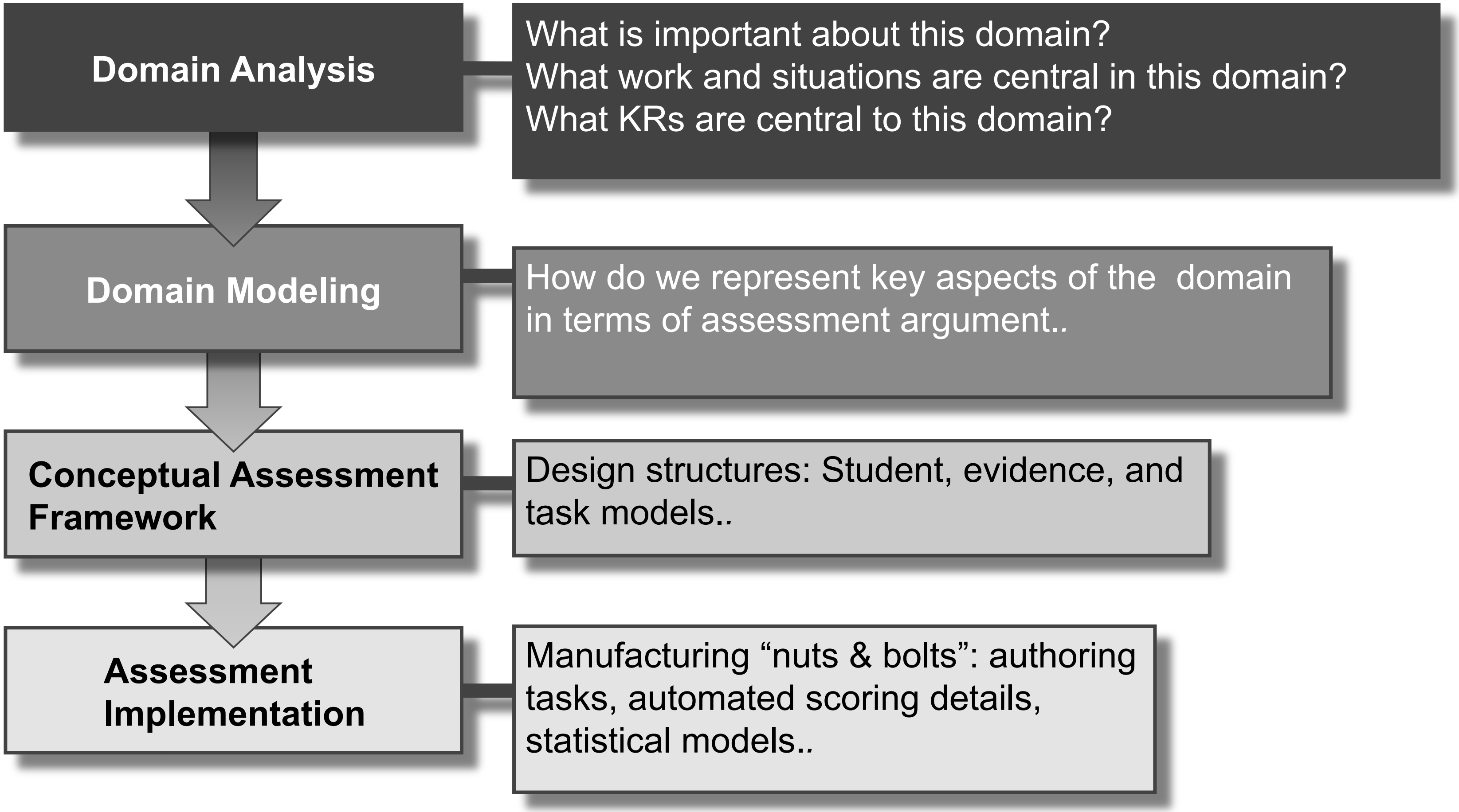

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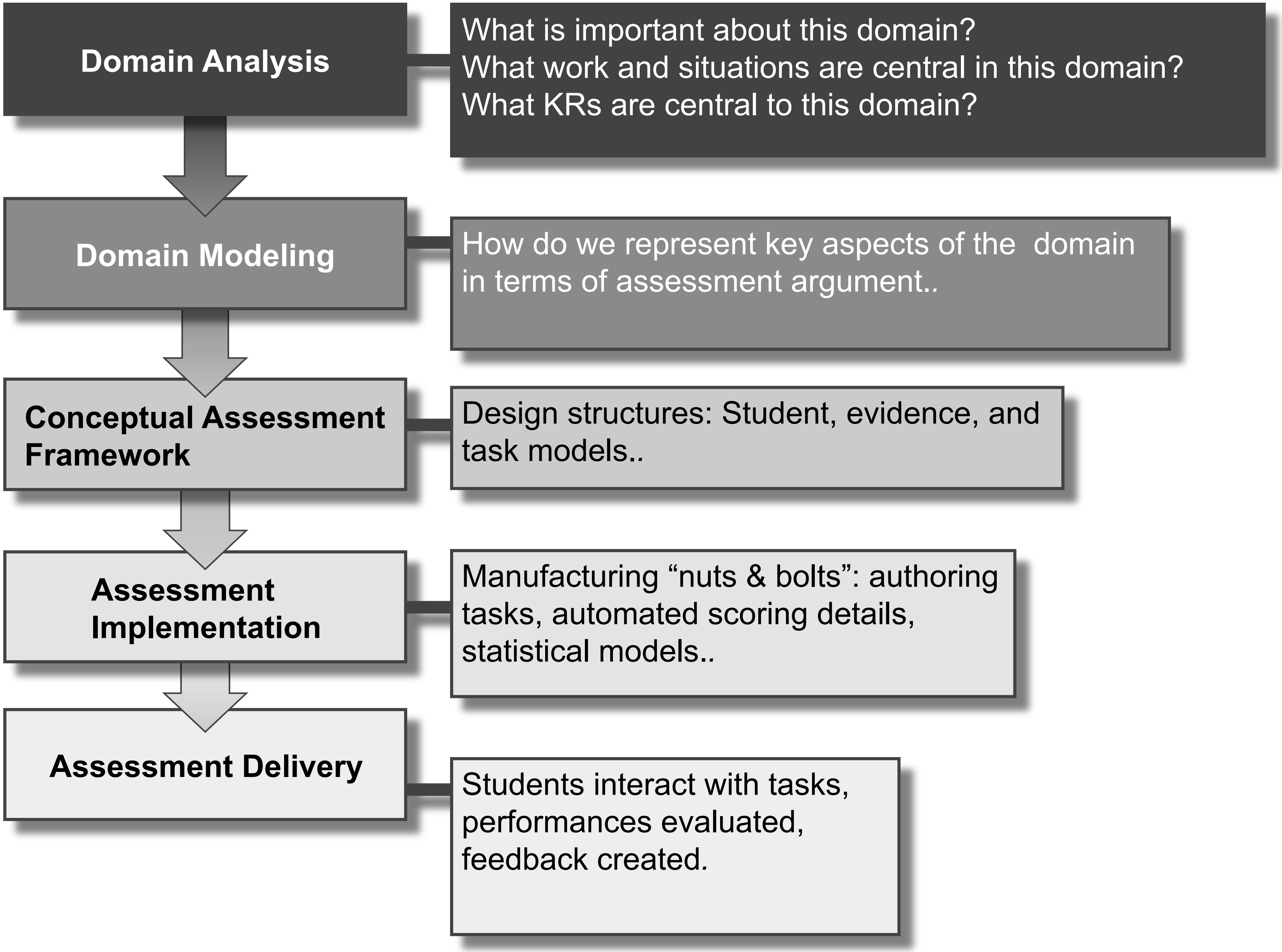

- From Mislevy & Riconscente, 2006

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Domain Analysis	What is important about this domain? What work and situations are central in this domain? What KRs are central to this domain?
Domain Modeling	How do we represent key aspects of the domain in terms of assessment argument..
Conceptual Assessment Framework	Design structures: Student, evidence, and task models..
Assessment Implementation	Manufacturing “nuts & bolts”: authoring tasks, automated scoring details, statistical models..
Assessment Delivery	Students interact with tasks, performances evaluated, feedback created.

- From Mislevy & Riconscente, 2006

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Principled Assessment of Computational Thinking (PACT)

How can we improve CS teaching, learning, and adoption through evidence-centered assessment?

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Projects

PACT I & II (2011-2014)

- Planning grant and follow on special project to conduct a CT domain analysis, and to design, develop and validate assessments for the *Exploring Computer Science* curriculum.

Computer Science in Secondary Schools: Studying Context, Enactment and Impact (CS3) (2014-2018)

- Large-scale implementation study of the *Exploring Computer Science* curriculum. Focus on investigating relationships between curriculum enactment and CT learning outcomes (using PACT assessments)

PACT Online (2014-2017)

- Developing and validating web-based, more dynamic/interactive versions of the ECS assessments, and integrate functionality with the CS10k web site

***Additional project details available:* http://pact.sri.com**

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Context: Principled Assessment for Computational Thinking (PACT)

Domain Analysis: Computational Thinking Practices	What is important about the computational thinking practices domain? What work and situations are central to the computational thinking domain? What KRs are central to the computational thinking domain?

- From Mislevy & Riconscente, 2006

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Domain Analysis Resources for Computational Thinking

Literature

- National Academies Report: Computer Science: Reflections on the Field, Reflections from the Field
- SIGCSE, CSTA, ITiCSE, Journal of Computing in Higher Education, Educational Researcher
- Jeanette Wing & others; National Academies Workshop on Pedagogical Aspects of Computational Thinking

Standards/Curriculum

- CSTA (2011). CSTA K-12 Computer Science Standards
- Exploring Computer Science
- College Board (2010). AP CS Principles: Big Ideas, Key Concepts, and Supporting Concepts
- NGSS, CCSS

Computational Thinking Practices

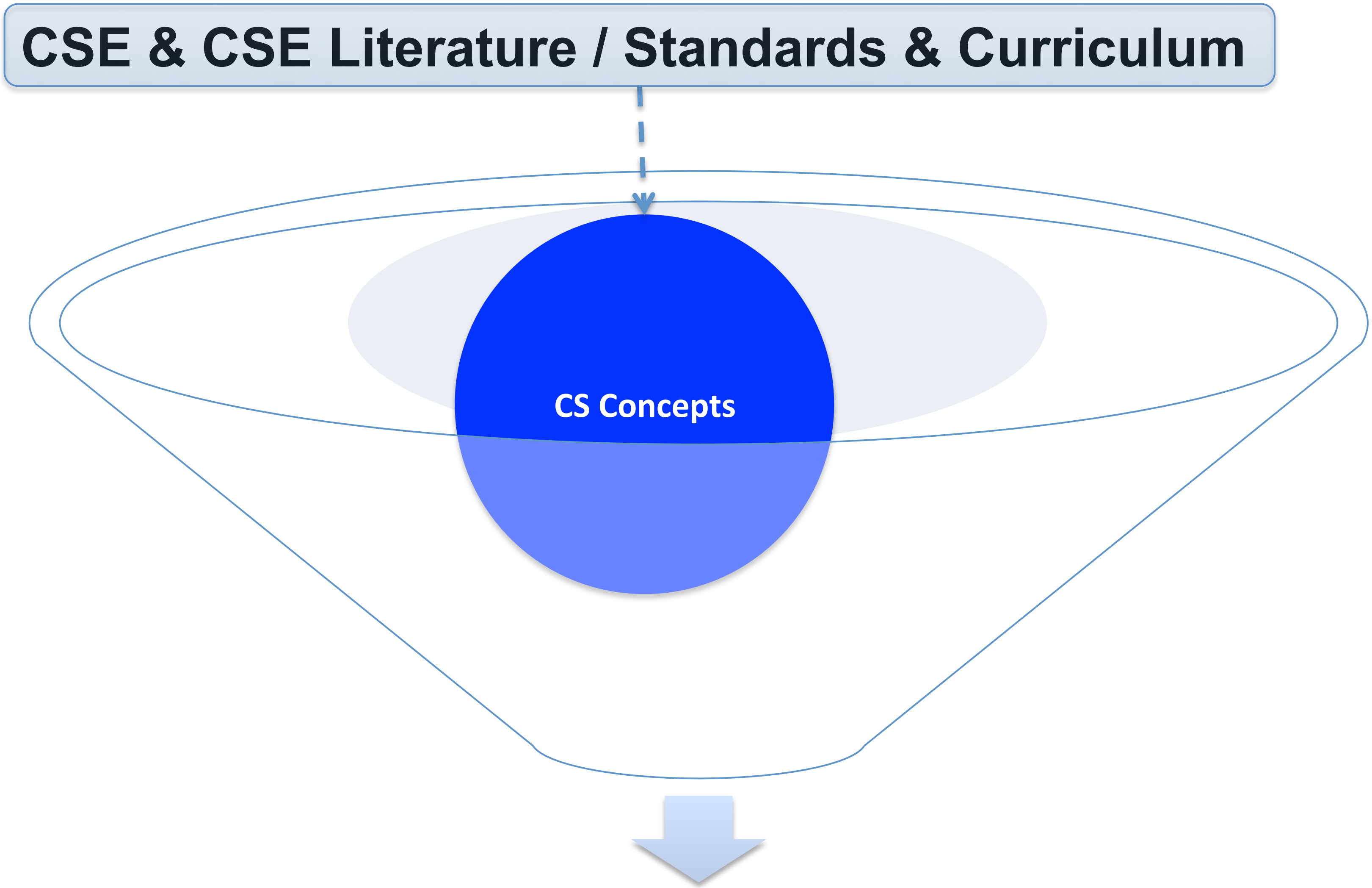
New high school curricula (e.g., CS Principles, ECS) emphasize "computational thinking **practices**".

This reflects an orientation toward not just an internal, individual "thinking" but **"ways of being and doing" that students should demonstrate** when learning and exhibiting computer science knowledge, skills, and attitudes.

Computational Thinking Practices

The **Common Core State Standards** include standards related to computational thinking practices in mathematics such as problem solving and abstraction.

The **Next Generation Science Standards** include standards dealing with engineering design and describe “using mathematical and computational thinking” as an essential practices for modeling and analyzing and interpreting data.



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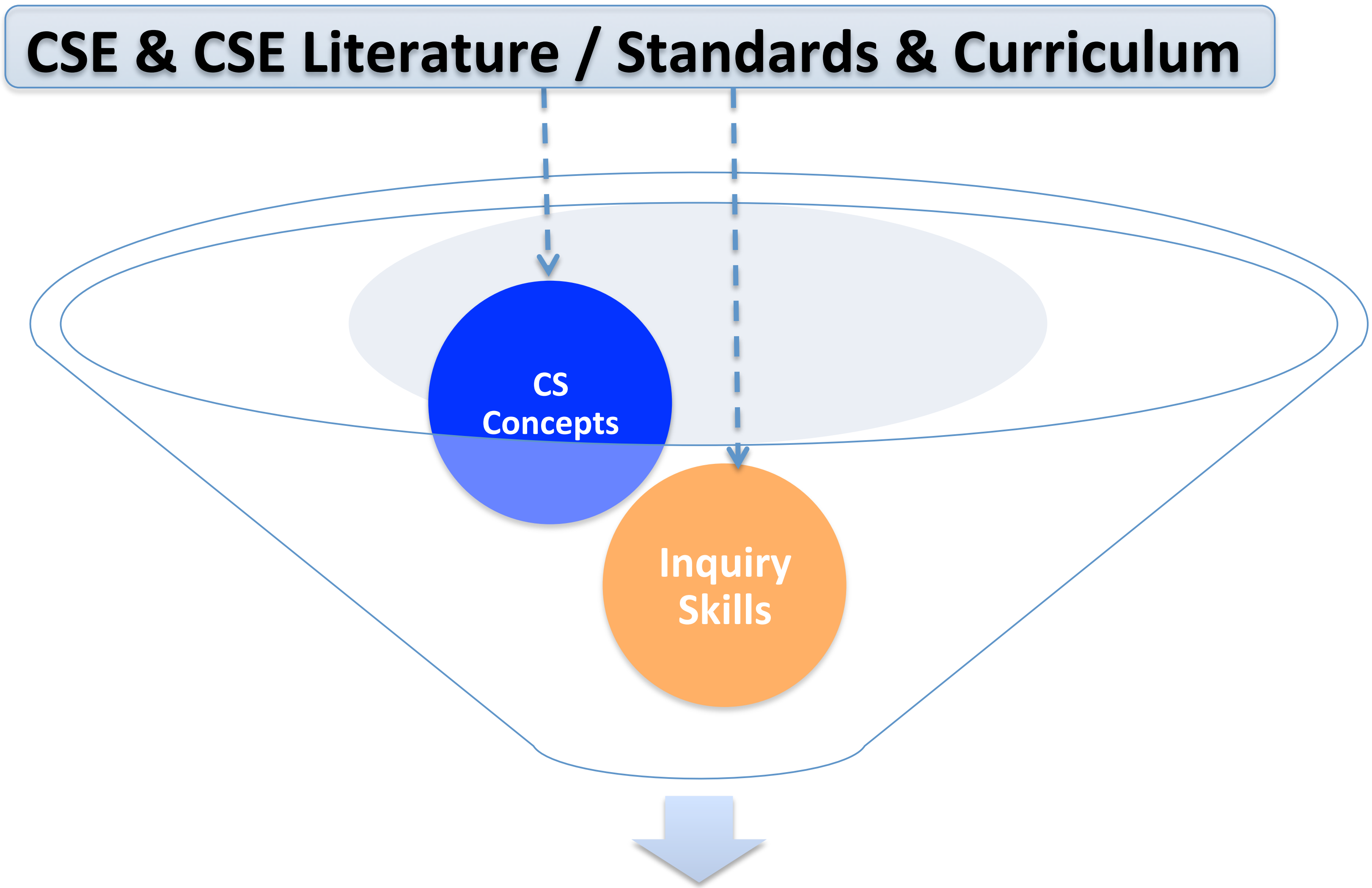
Computational Thinking Practices

Example CS Concepts		
Algorithms		
Programming		
Recursion		
Abstraction		
Debugging / Testing		
Variables		



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Computational Thinking Practices

Example CS Concepts	Example Inquiry Skills	
Algorithms	Evaluate	
Programming	Explore	
Recursion	Analyze	
Abstraction	Explain	
Debugging / Testing	Elaborate	
Variables	Model	

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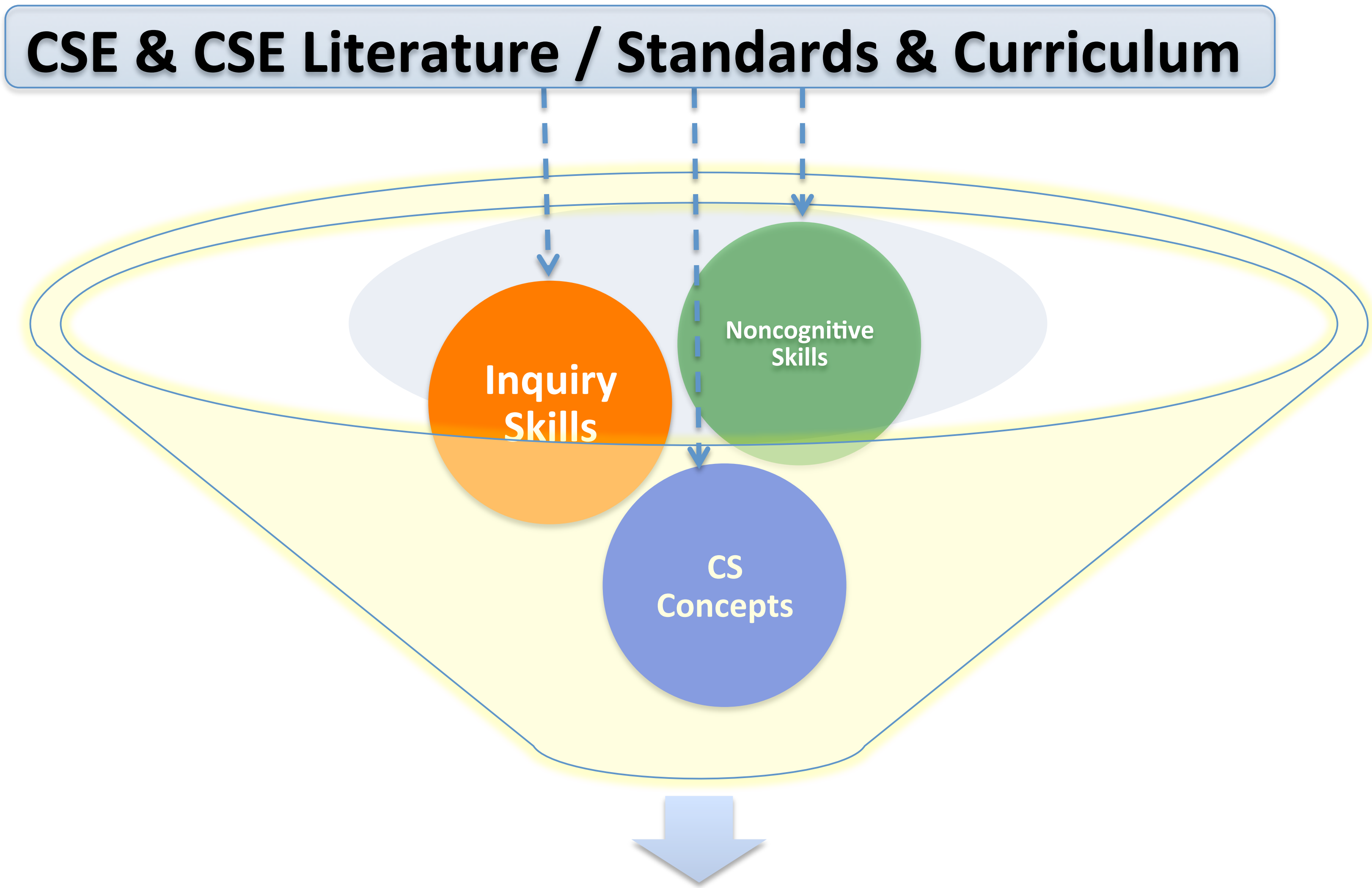


Computational Thinking Practices

Computational Thinking Practices

Example CS Concepts	Example Inquiry Skills	Example Noncognitive Skills
Algorithms	Evaluate	Communication
Programming	Explore	Teamwork/collaboration
Recursion	Analyze	Leadership
Abstraction	Explain	Self-efficacy
Debugging / Testing	Elaborate	Self-concept
Variables	Model	Persistence

Computational Thinking Practices

Computational Thinking Practices

Example CS Concepts	Example Inquiry Skills	Example Noncognitive Skills
Algorithms	Evaluate	Communication
Programming	Explore	Teamwork/collaboration
Recursion	Analyze	Leadership
Abstraction	Explain	Self-efficacy
Debugging / Testing	Elaborate	Self-concept
Variables	Model	Persistence

Analyze their computational work and the work of others

Computational Thinking Practices

Example CS Concepts	Example Inquiry Skills	Example Noncognitive Skills
Algorithms	Evaluate	Communication
Programming	Explore	Teamwork/collaboration
Recursion	Analyze	Leadership
Abstraction	Explain	Self-efficacy
Debugging / Testing	Elaborate	Self-concept
Variables	Model	Persistence

Collaborate with peers on computing activities

Context: Principled Assessment for Computational Thinking (PACT)

Domain Modeling:

Computational Thinking Practices

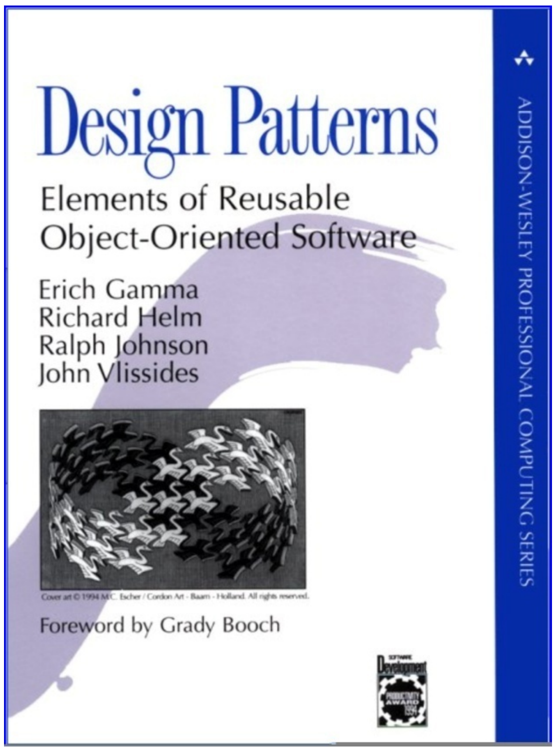
How do we conceptualize and represent key aspects of the computational thinking domain in terms of an assessment argument?

What are Design Patterns?

- Solution to a problem that occurs repeatedly in our environment
- Specified at a level of generality that the underlying approach can be applied across many situations while adapting to the particulars of each case
- Shows general relationships and interactions without specifying details

What are Design Patterns?

- Design Patterns in Computer Science & Software Engineering



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What are Design Patterns?

In this computer science and software engineering, design patterns:

- Help programmers tackle complex problems that recur in different guises
- Provide structured insights into conceptual problems and solutions above the level of specific programming languages and implementation environments
- Object-oriented design patterns

Domain Modeling & Design Patterns

- Specifies and organizes assessment argument in narrative form based on information from Domain Analysis
- High-level representation of assessment argument
- Transition point between specialized knowledge about the domain to the specialized knowledge about the more technical machinery of assessment

Motivation for Assessment Design Patterns

- Serve as an interstitial document that allows different assessment stakeholder groups to understand important aspects of assessment
- They lay out a design space for developers
  - Choices, connections, coherence, tradeoffs, examples
- Attributes reflect assessment argument structure
- Can improve both efficiency & validity

Developing Design Patterns

- An iterative, interdisciplinary process requiring:
  - Content experts
  - Educators
  - Assessment experts
  - Practitioners
  - Multiple sources of information (e.g., education research, curriculum examples, existing standards, industry trends, policy documents)

Assessment Design Pattern Attributes

Overview

- Description of construct being modeled in design pattern.

Focal Knowledge, Skills & Attributes (KSAs)

- The primary KSAs targeted by the design pattern. What we want to make inferences about.

Additional KSAs

- Other KSAs that may be required for successful performance on the assessment tasks.

Assessment Design Pattern Attributes

Potential Observations

- *Features* of the things students say, do, or make that constitute the evidence.

Potential Work Products

- Some possible things one could see students doing that would give evidence about the KSAs.

Characteristic Features

- Aspects of assessment situations that are likely to evoke the desired evidence.

Variable Features

- Aspects of assessment situations that can be varied in order to shift difficulty or emphasis.

Context: Principled Assessment for Computational Thinking (PACT)

- Developed design patterns for:
  - Six computational thinking practices (CTPs)
    - Analyze the effects of developments in computing
    - Design and implement creative computational solutions and artifacts
    - Design and apply abstractions and models
    - Analyze computational work (both own and others)
    - Communicating computational thought processes, procedures and results to others
    - Collaborate with peers on computing activities

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Context: Principled Assessment for Computational Thinking (PACT)

- Developed design patterns for:
  - ECS units 1-4
    - Human-computer interaction
    - Problem solving
    - Web design
    - Introduction to programming

Context: Principled Assessment for Computational Thinking (PACT)

ECS Units	Computational Thinking Practices
Unit 1: Human-Computer Interaction	• Analyze the effects of developments in computing.
Unit 2: Problem Solving	• Design and implement creative solutions and artifacts. • Apply abstractions and models. • Analyze their computational work and the work of others.
Unit 3: Web Design	• Design and implement creative solutions and artifacts. • Analyze their computational work and the work of others. • Connect computation with other disciplines.
Unit 4: Introduction to Programming	• Design and implement creative solutions and artifacts. • Apply abstractions and models. • Analyze their computational work and the work of others.

Context: Principled Assessment for Computational Thinking (PACT)

ECS Unit / CTP	Example Unit FKSAs	Example CTP FKSAs
Unit 1: Human-Computer Interaction ↕ Analyze the effects of developments in computing.	• Students are able to explain why an object is or is not a computer.	• Ability to describe the characteristics of a computer (including what it means for a computer to be "intelligent").
	• Students are able to evaluate the implications of a form of data exchange on social interactions.	• Ability to analyze the effects of computing on society within economic, social, and cultural contexts.
	• Students are able to explain how computing innovation has led to new types of legal and ethical concerns.	• Ability to evaluate legal and ethical concerns raised by computing-enabled innovations.

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Context: Principled Assessment for Computational Thinking (PACT)

Example Design Pattern, Unit 1: Human-Computer Interaction

Overview (from curriculum)

In Unit 1 students are introduced to the major components of the computer, including: input, output, memory, storage, processing, software, and the operating system. Students consider how Internet elements are organized, engage in effective searching, and focus on productive use of email. Fundamental notions of Human Computer Interaction (HCI) and ergonomics are introduced.

Students learn that "intelligent" machine behavior is not "magic" but is based on algorithms applied to useful representations of information. Students learn the characteristics that make certain tasks easy or difficult for computers, and how these differ from those that humans characteristically find easy or difficult. Students gain an appreciation for the many ways (types of use) in which computers have had an impact across the range of human activity, as well as for the many different fields in which they are used. Examples illustrate the broad, interdisciplinary utility of computers and algorithmic problem solving in the modern world.

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Context: Principled Assessment for Computational Thinking (PACT)

Example Design Pattern, Unit 1: Human-Computer Interaction

Example Focal Knowledge, Skills & Attributes (KSAs)

- Students are able to explain why an object is or is not a computer.
- Students are able to evaluate the implications of a form of data exchange on social interactions.
- Students are able to explain how computing innovation has led to new types of legal and ethical concerns.

Context: Principled Assessment for Computational Thinking (PACT)

Example Design Pattern, Unit 1: Human-Computer Interaction

Example FKSA	Example Potential Work Product	Example Potential Observations
Students are able to explain why an object is or is not a computer.	An explanation of why an object is or is not a computer.	Appropriateness of the explanation of why an object is or is not a computer. • Did the student correctly identify aspects of the object that relate to aspects of a computer? • Did the student correctly identify aspects of a computer that the object lacks?

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Context: Principled Assessment for Computational Thinking (PACT)

Example Design Pattern, Unit 1: Human-Computer Interaction

Example FKSA	Example Characteristic Features	Example Variable Features
Students are able to explain why an object is or is not a computer.	The student must be presented with an object The object must have clear characteristics that allow the evaluation of whether it is a computer.	Whether the object could be considered a computer or not. Whether students would be able to argue either way if the object is a computer or not. The degree to which the important characteristics are explicitly stated in the problem or must be inferred by the test taker.

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Context: Principled Assessment for Computational Thinking (PACT)

Example Assessment Task, Unit 1: Human-Computer Interaction

You and your friend are debating about whether or not a microwave is a computer.

Explain why you think a microwave IS or is NOT a computer. In your response describe at least TWO characteristics of a computer that support your explanation.

A microwave (check one) _____ IS a computer _____ is NOT a computer

Explain:

Context: Principled Assessment for Computational Thinking (PACT)

Example Assessment Task, Unit 1: Human-Computer Interaction

You and your friend are debating about whether or not a microwave is a computer.

Explain why you think a microwave IS or is NOT a computer. In your response describe at least TWO characteristics of a computer that support your explanation.

A microwave (check one) _____ IS a computer _____ is NOT a computer

Explain:

FKSA:

Students are able to explain why an object is or is not a computer.

Context: Principled Assessment for Computational Thinking (PACT)

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Explain why you think a microwave IS or is NOT a computer. In your response describe at least TWO characteristics of a computer that support your explanation.

A microwave (check one) _____ IS a computer _____ is NOT a computer

Explain:

Potential Work Product:

An explanation of why an object is or is not a computer.

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Characteristic Features:

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The object must have clear characteristics that allow the evaluation of whether it is a computer.

Context: Principled Assessment for Computational Thinking (PACT)

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A microwave (check one) _____ IS a computer _____ is NOT a computer

Explain:

Variable Features:

The degree to which the important characteristics are explicitly stated in the problem or must be inferred by the test taker.

Whether students would be able to argue either way if the object is a computer or not.

Context: Principled Assessment for Computational Thinking (PACT)

Example Scoring Rubric, Scoring Guidance
Total Points Possible for a): 2

The points are given based on the explanation – the explanation should relate what a microwave can do to an aspect of a computer (the aspect could be something other than what we specified here).

Defining aspects (characteristics) can include things such as reducing human effort, taking inputs, giving outputs, stores data, processes information

1 point for listing 2 valid aspects of a computer. Response must name specific terms, such as input, output, process, data, programming, instructions, etc.

1 point for relating microwave to the aspect(s) they identify.

If they only name one aspect and relate it to the microwave then they should be scored 1 point.

Misconceptions about microwaves and how they work don't count against score.

Context: Principled Assessment for Computational Thinking (PACT)

Example Scoring Rubric, Scoring Guidance w/ Potential Observation

The points are given based on the explanation – the
relate what a microwave can do to an aspect of a co
could be something other than what we specified he

Defining aspects (characteristics) can include things
human effort, taking inputs, giving outputs, stores da
information

1 point for listing 2 valid aspects of a computer. Response must name specific terms, such as input, output, process, data, programming, instructions, etc.

1 point for relating microwave to the aspect(s) they identify.

Did the student correctly identify aspects of the object that relate to aspects of a computer?

Context: Principled Assessment for Computational Thinking (PACT)

Example Scoring Rubric, Exemplar Responses

Example 1 point response:
“It is programmed to heat up or unfreeze food.”(+1 programmed to heat up or unfreeze)

Example 2 point responses:
"The microwave has data and it does have a processor because when you push the time (numbers) show up on the screen and when I push start, it started the time starts and the food starts cooking".

“Yes, it is a computer because it is given command when we press buttons on it (+1 for has input by pressing a button) and put a timing on the food.” (+1 for has output by timing food)

“A microwave is a computer because its programmed (+1 program to heat up food) to help us heat up our food when its cold we can also program the time of day to let us know what time it is.” (+1 program the time)

Closing Comments

Teaching Questions	Assessment Questions
What are the main knowledge and skills students should learn?	What complex of knowledge, skills, or other attributes should be assessed?
What evidence from classroom activities will help best determine how well students are learning the desired knowledge and skills?	What behaviors or performances should reveal those constructs?
What classroom activities will help students learn the desired knowledge and skills?	What tasks or situations should elicit those behaviors?

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Closing Comments

- Assessment arguments and evidence-centered design.
- Assessment design patterns.
- Slides and handouts will be available on the Publications page at:

  http://pact.sri.com

Closing Comments

Future directions for research in K-12 computer science –

- Analyze and Operationalize the Computational Thinking Domain
- Define, Model and Validate Learning Progressions
- Understand the Intellectual Demands Computer Science Work
- Understand Implementation Factors and their Impact on Student Learning
- New Pedagogies for Cross-Domain, CT Constructs

From: Bienkowski, M. & Snow, E. (2014). *Building evidence and building practice in Computer Science education*: White paper presented at the 2014 CS education research summit.

Thank You!

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