K-12 Engineering Education

INSPIRE – Purdue Perspective

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INSPIRE! Institute *for* P-12 Engineering Research *and* Learning

PURDUE ENGINEERING EDUCATION

PURDUE UNIVERSITY

Discussion Points

- What is INSPIRE?
- Context of P-12 Engineering
- Conceptualizing P-12 Engineering
- Examples of research, engagement and resources

INSPIRE

- Conducts basic and applied multidisciplinary research focused on four main areas:
  - Teacher professional development
  - Assessment
  - Student Learning
  - Informal Learning
- Components of work encompasses outreach with teachers, schools and school districts and partnerships with educational constituents.
- Has impacted 600+ teachers and 17,000+ students

Vision & Mission

- **OUR VISION**
  - To create an engineering literate society through preeminence in P-12 engineering education, research, and scholarship.
- **OUR MISSION**
  - To study engineering thought and learning at the P-12 level and to inspire diverse students to pursue engineering and science of the benefit of humanity and the advancement of society.

55 members including undergraduate researchers

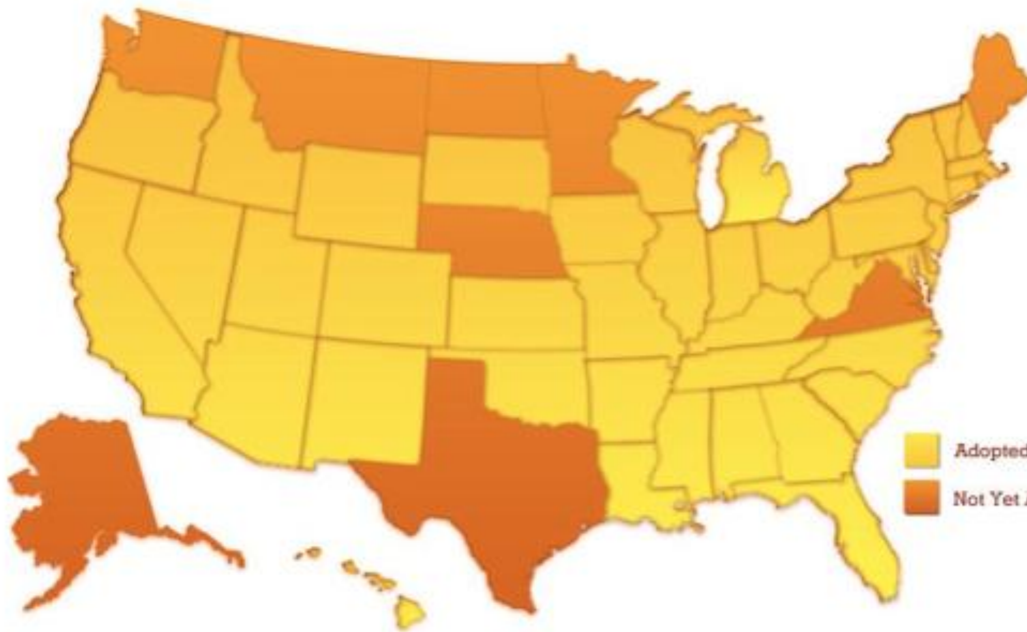
Global Calls to Action

"*Education as usual*" will not get us there

"*Business as usual*" will not get us there

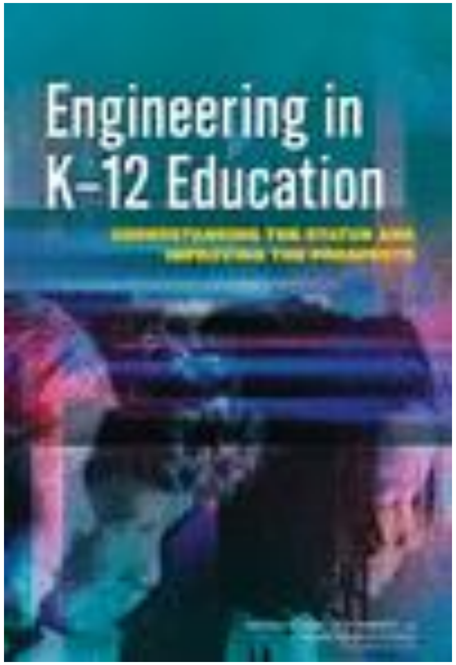
P-12 Engineering - Context: Core Competencies/Science Standards/NAEP

- Framework for New Science Education Standards, 2010-2011
  - Explicitly including engineering
- National Assessment of Educational Progress (NAEP)
  - US K-12 students will be assessed on Technology and Engineering 2014 (two grade levels)

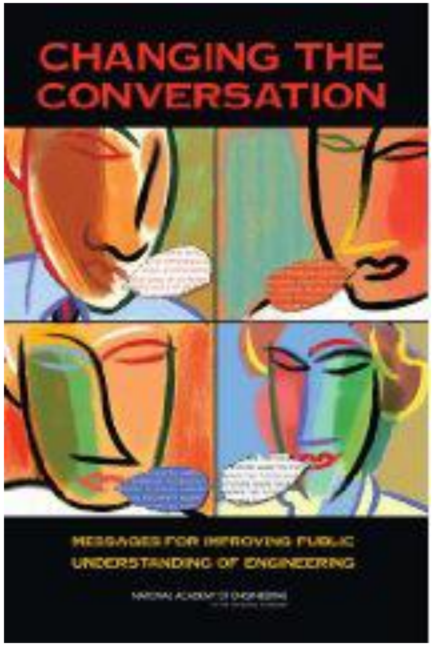


http://www.corestandards.org/in-the-states

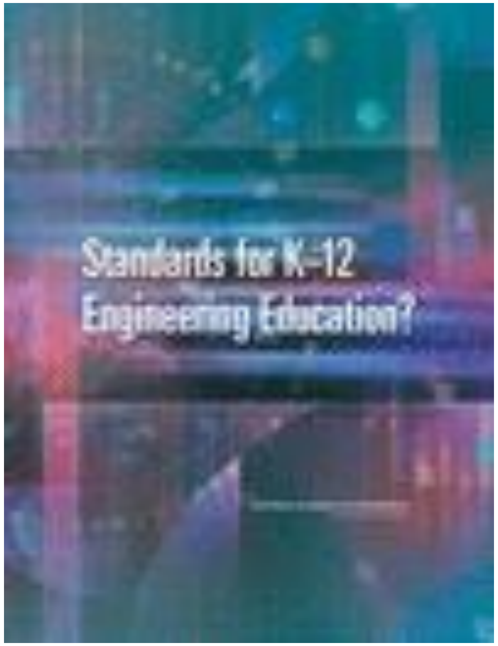
Engineering in K-12 - Trends and Issues



Engineering in K-12 Education: Understanding the Status and Improving the Prospects, 2009



Changing the Conversation - Public Messages on Engineering



Standards for K-12 Engineering Education?, 2010

- No standalone standards
- Integration
- A follow-up study on integration

STEM in P-12 in the US

- **Early**

Girls and underrepresented minorities "loose interest"/disengage as early as 2nd / 3rd grade

- **Integrated**

Not another silo. Why actually teach math and science as separate units in elementary?

- **Social Good**

Consistently in P-16, "positive" reasons for leaving Engineering or STEM fields are to pursue social good

Engineering in P-12

- **Early Engineering**

Building a technologically literate society (engineering by all and for all), happens before higher education and outside of higher-education trained engineers

- **Pre-Engineering**

Preparing students for college and workplace engineering (career paths and pipeline)

- **Engineering of Educational Systems**

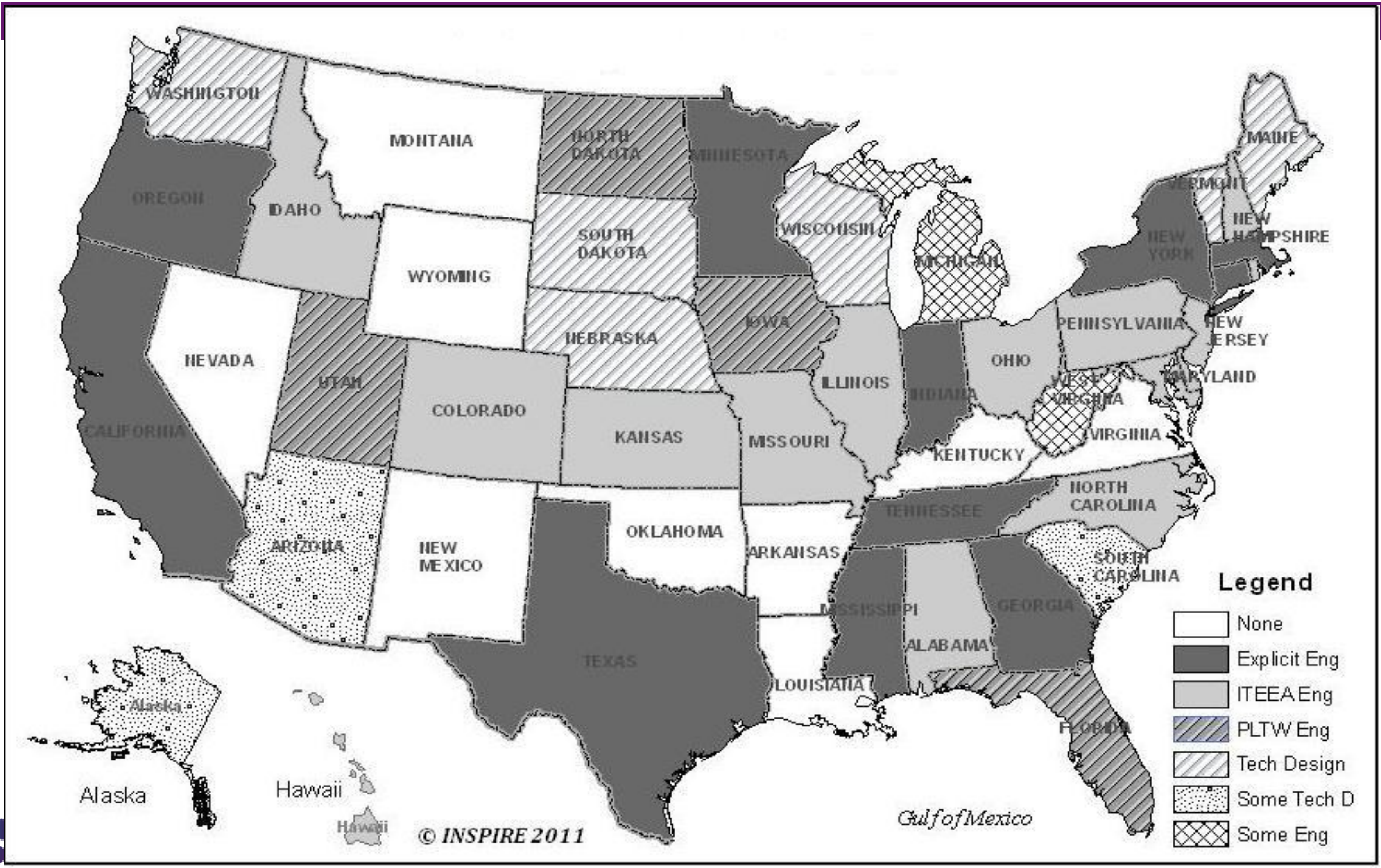
Education as a system that can benefit from an engineering perspective

Desperate research needed

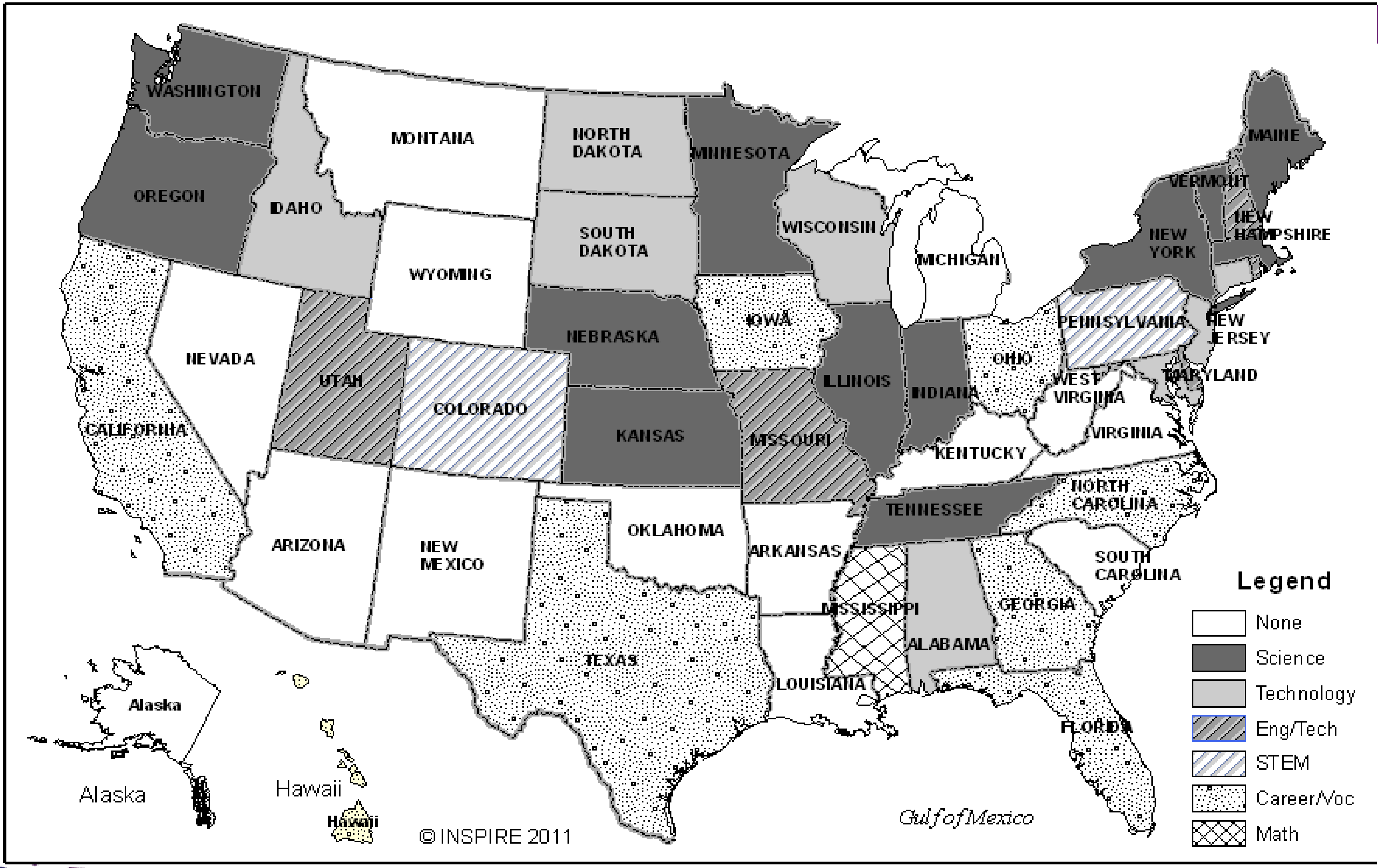
- What does it take to educate in-service teacher to integrate engineering? (diffusion, expertise)
- What models of integration work better under which conditions?
- Learning progressions of students (i.e. what is the ceiling of what a second grader can know about design, optimization, trade-off)
- How to reconcile the the stereotypes of engineering, the traditional practice of engineering and new emergent models of engineering

States by Type of Engineering

Carr, R., Bennett, L. & Strobel, J. (2012). Engineering in the K-12 STEM Standards of the 50 U.S. States: An Analysis of Presence and Extent. Journal of Engineering Education, 101, 3, 539–564.



States by Content Area



Big Ideas Conveyed in Standards

Example from Standards

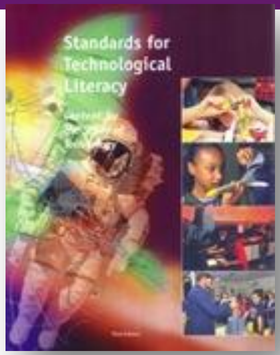
Science Common Core
Core and Component Ideas in Engineering, Technology, and Applications of Science Core Idea ETS1: Engineering Design
ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution
Core Idea ETS2: Links among Engineering, Technology, Science, and Society
ETS2.A: Interdependence of Science, Engineering, and Technology
ETS2.B: Influence of Engineering, Technology and Science on Society and the Natural World

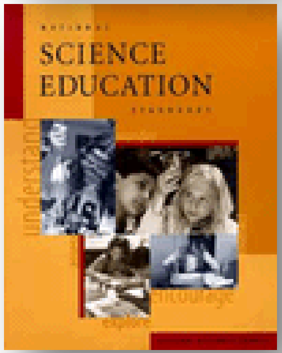
K-8 Indiana Science Standards
Science, Engineering, and Technology

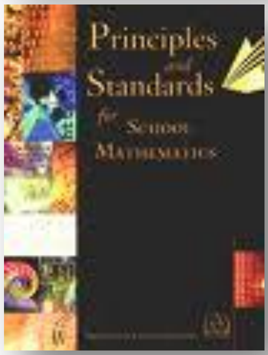
1.4 Determine properties of natural and man- made materials and their most important uses.
2.4 Describe how technologies have been developed to meet human needs.
3.4 Define a real world problem and list criteria for a successful solution.
4.4 Design a moving system and measure its motion.
5.4 Design a prototype that replaces a function of the human body part.
6.4 Apply a form of energy to design and construct a simple mechanical device.
7.4 Design and construct a device that converts energy from one form to another to perform work.
8.4 Identify the appropriate materials to be used to solve a problem based on their specific properties and characteristics.

National Standards

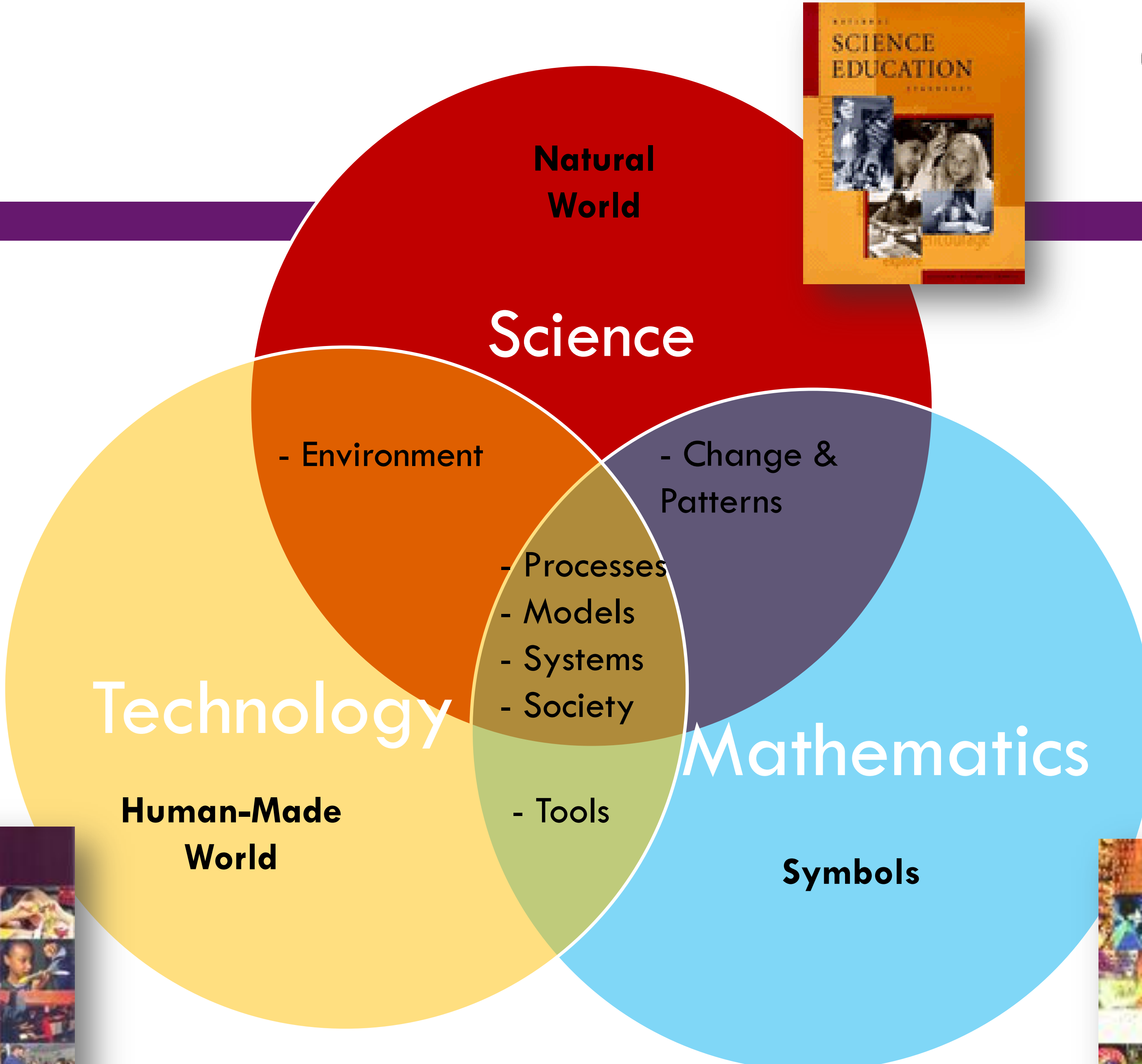
- Review of three major publications for investigating STM standards core concepts
  - ✓ Standards for **Technological** Literacy (ITEEA, 2007)
    National **Science** Education Standards (NRC, 1996)
  - ✓ Principles and Standards for School **Mathematics** (NCTM, 2000)







Prof. Senay Purzer


Natural World
Science
- Environment
- Change & Patterns
- Processes
- Models
- Systems
- Society
Technology
Mathematics
- Tools
Human-Made World
Symbols
SCIENCE EDUCATION


Standards for Technological Literacy


Principles and Standards for School Mathematics

Results

- The STM commonalities

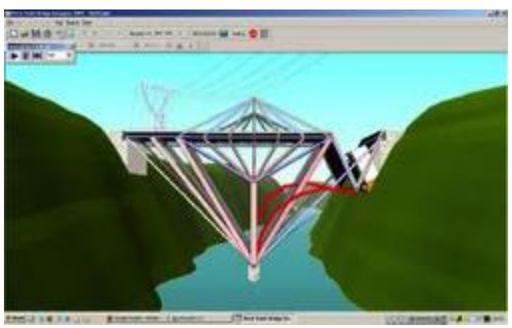
	Process	Modeling	Systems	Societal Impact
Science	Inquiry	Scientific Models	Natural systems	Knowledge
Technology	Design	Technological Models	Manufac. systems	Tools
Mathematics	Problem-solving	Mathematical Models	Measurement systems	Analysis
	Iterative	*Communication*	*Order & Organization*	*STM Link*

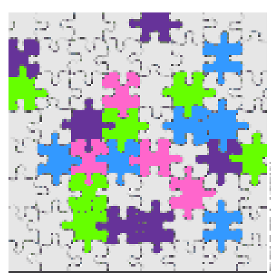
Parents & Caregivers' Roles in Education

(Yun et al. 2010)

- Motivate children to learn particular topics
  - And pursue certain fields of study, careers
- Promote attitudes towards different topics
  - Promote interest in science; fear of mathematics, etc.
- Stimulate student achievement
  - Providing tutoring, help, encouragement, etc. to do well in school
- Thinking guides
  - Can help children learn to think like a scientist or like an engineer
  - By promoting inquiry & design skills

What do parents do to help their children learn about engineering?





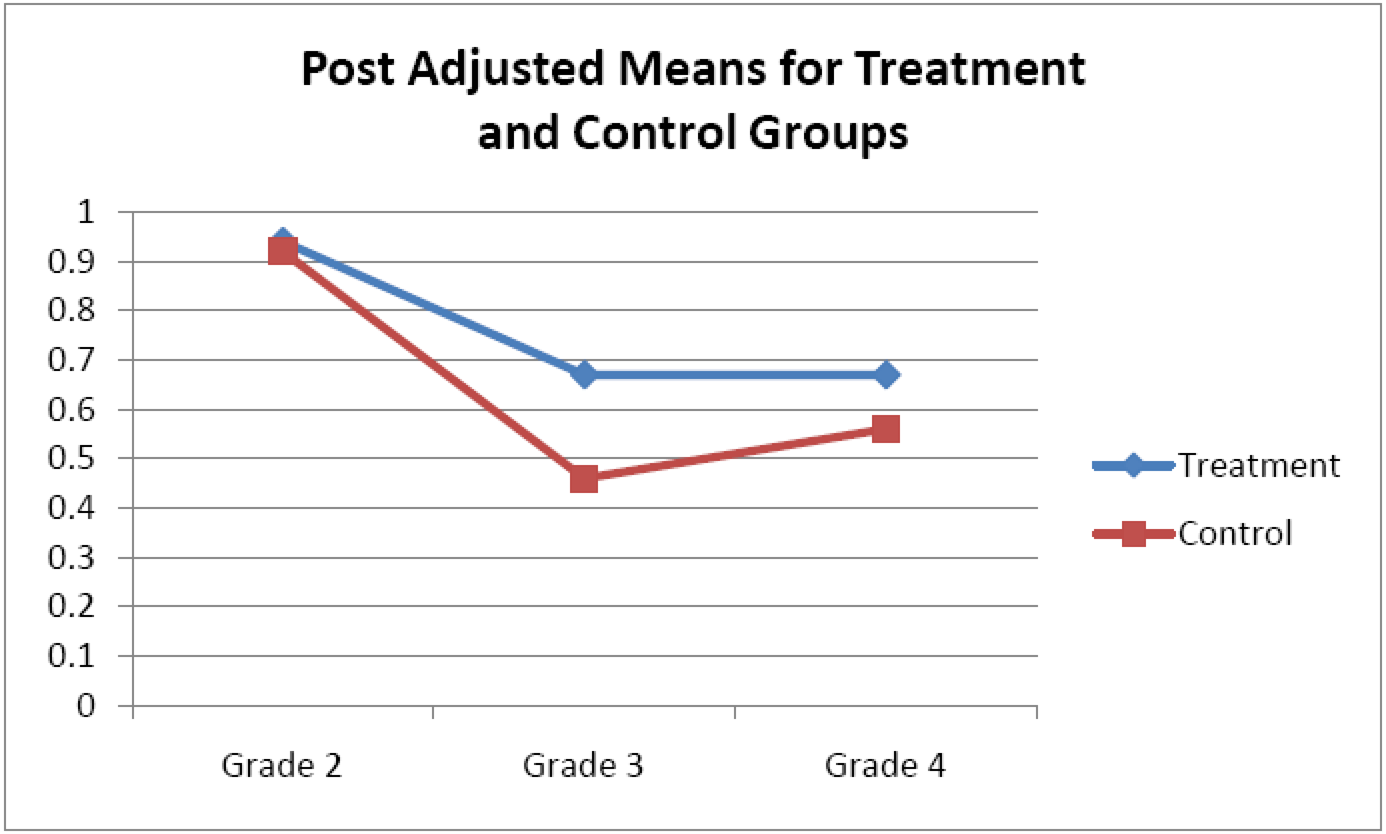
QUALITY CYBER-ENABLED, ENGINEERING EDUCATION PROFESSIONAL DEVELOPMENT TO SUPPORT TEACHER CHANGE AND STUDENT ACHIEVEMENT (E2PD) –YEAR 1 DATA

PI: Dr. Heidi Diefes-Dux; Co-PIs: Dr. Sean Brophy, Dr. Monica Cardella, and Dr. Johannes Strobel

Student Knowledge Tests – All items

- Grade 2: no significant effects
- Grade 3: significant effects of treatment group
- Grade 4: significant effects of treatment group
  - Interaction effect of Title 1 status

Student Knowledge Tests - Post knowledge scores for the treatment and control groups for each grade level on all items



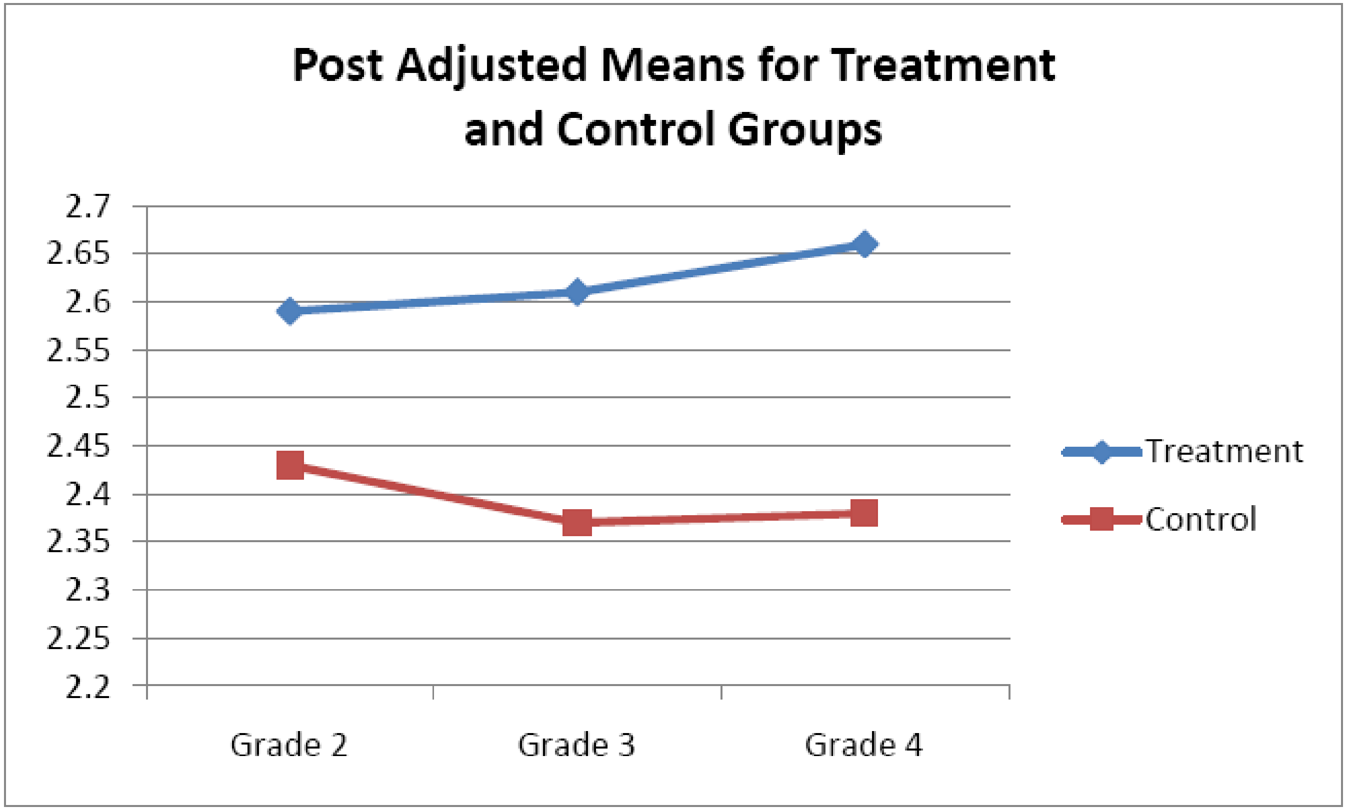
Note: The scale is from 0 to 1.

Engineering Identity Scale (EIDS)

- The EIDS consists of four subscales
- Pre to post differences for the EIDS score for each subscale
- Significant results at all grades on EIDS in treatment group
- No significant pre to post differences on any subscale for the control group students.

Developed by Brenda Capobianco, Purdue

Post EIDS Scores for Treatment and Control Groups by Grade



Note: The scale is from 1 to 3.

Example – Pre DAET Triangulation

Pre-DAET *"original text"/(interpretation)*	
Students drew an engineer constructing a building.	Students drew an engineer fixing a car.
	
"An engineer is someone who builds things like houses and tall buildings."	"My engineer is fixing a car. So it could be cool so she can go home after she is finished and she her family."/ (My engineer is fixing a car. So it could be cool so she can go home after she is finished and see her family.)

Example – Post DAET Triangulation

Post-DAET *“original text”/(interpretation)*	
 “Using the Engineer desighn prosess to make a ice cream contraption. (process: 1 ask, 2 plan, 3 build, 4 test, 5 improve, and 6 show.)” /([My engineer is] using the engineering design process to make an icecream contraption. The process is to: (1) ask, (2) plan, (3) build, (4) test, (5) improve, and (6) show.)	 “Designing better long lasting bubble gum. He is testing it out and triying to figure out improvements.”

Expertise development - Model

Sun, Y. & Strobel, J. (2012)

Stages of EEE Expertise Development	Contextualization of Engineering Learning		Development of Teaching Pedagogy		Making Interdisciplinary Connections	
Stage I: Mechanical Imitator	I-1: Focusing solely on delivery of engineering content with little efforts made to contextualize engineering teaching in terms of accomodating engineering learning and relating engineering to life	De-contextualized	I-2: Sticking to the engineering teaching procedures and steps as learned in professional development with no particular teaching strategies and methods used to address engineering learning problems and issues	Absent	I-3: Having no idea how engineering can be integrated into the teaching and learning of other disciplines	Non-connected
Stage II: Skillful Imitator	II-1: Taking initial steps to accomodate engineering learning needs and relating engineering to real life		II-2: Relying mostly on the engineering teaching procedures and steps learned in professional development but being able to apply some generic teaching strategies and methods to address engineering learning problems and issues		II-3: Becoming aware of some potential opportunities to integrate engineering into the teaching and learning	
Stage III: Adaptor	III-1: Demonstrating deeper understanding about engineering learning needs and becoming more capable of accomodating engineering learning needs and allowing students to see how engineering is related to real life		III-2: Being able to develop some engineering teaching strategies and methods to deal with engineering problems and issues		III-3: Being able to find some opportunities to connect existing engineering activities with the teaching and learning of other disciplines but engineering is still largely appended in such connections	
Stage IV: Improver	IV-1: Carrying out engineering teaching based on perceived engineering learning needs and through hands-on and exploratory experiences		IV-2: Improving engineering learning outcomes by making appropriate changes to engineering teaching materials, procedures, and/or steps of engineering learned in professional development		IV-3: Being able to make more comprehensive interdisciplinary connections between engineering and other disciplines	
Stage V: Creator	V-1: Contextualizing engineering teaching and learning by making engineering knowledge enderstandable and meaningful to learners, and creating opportunities to experience the relevance of engineering through problem solving and real world applications	Contextualized	V-2: Creating new and appropriate ways of teaching engineering and creating new engineering and creating new engineering activities that help overcome contextual constraints and promote engineering thinking	Well-developed	V-3: Being creative in making interdisciplinary connections that allow students to learn non-engineering disciplines through new lenses and to learn engineering through practical applications	Well-connected

Adoption - Model

Stages of Adoption	Perception of Practicality and Sustainability of EEE		Comfort Level with Engineering Teaching		Perception of EEE Benefit to Elementary Students		Degree of Engineering Integration	
Stage I: Attempter	I-1: Overwhelmed by the perceived barriers to EEE and regarding EEE as impractical and unsustainable because of the perceived barriers	Teacher-centered	I-2: Feeling unconfident in one's engineering knowledge and uncomfortable with teaching engineering	Unconfident, Uncomfortable	I-3: An "engineering as anti-illiteracy" view about EEE benefits	Simple, Limited	I-4: Treating engineering teaching as isolated and as an add-on and teaching engineering discontinuously and sporadically	Passive, Isolated, Sporadic
Stage II: Adopter	II-1: Fully aware of the perceived barriers of EEE but viewing engineering as practical in elementary classrooms		II-2: Feeling somewhat confident in one's engineering knowledge and comfortable with teaching engineering		II-3: An "engineering as an expansion" view about EEE benefits		II-4: Making attempts of integrating engineering teaching and learning into the teaching and learning of other disciplines with shortened time gaps between engineering teaching	
Stage III: Ameliorator	III-1: Proving EEE practically through engineering teaching practice and becoming conscious of how to make EEE sustainable		III-2: Feeling confident in one's engineering knowledge and comfortable with teaching engineering		III-3: An "engineering as application and enrichment" view about EEE benefits		III-4: Practice engineering teaching on regular basis and making widespread connections between engineering and other disciplines	
Stage IV: Advocator	IV-1: Convinced of EEE practicality based on successful personal experience and making efforts to make EEE sustainable	Student-centered	IV-2: Feeling fully confident in one's engineering knowledge and fully comfortable with teaching engineering	Confident, Comfortable	IV-3: An "engineering as empowerment" view about EEE benefits	Comprehensive, Broad	IV-4: Making engineering teaching an integral part of teaching practice and making systematic connections between engineering and other disciplines	Active, Connected, Regular

Curricula: Model-Eliciting Activities

- Realistic **open-ended** problems with a client
- Require **team** of problem solvers
- Product is the **process** for solving the problem
  - End product is a **mathematical model** for client to use

MEA Principles
Model creation
Realistic
Self-assessment
Documentation
Shareable & Reusable
Effective prototype

Prof. Heidi Diefes-Dux

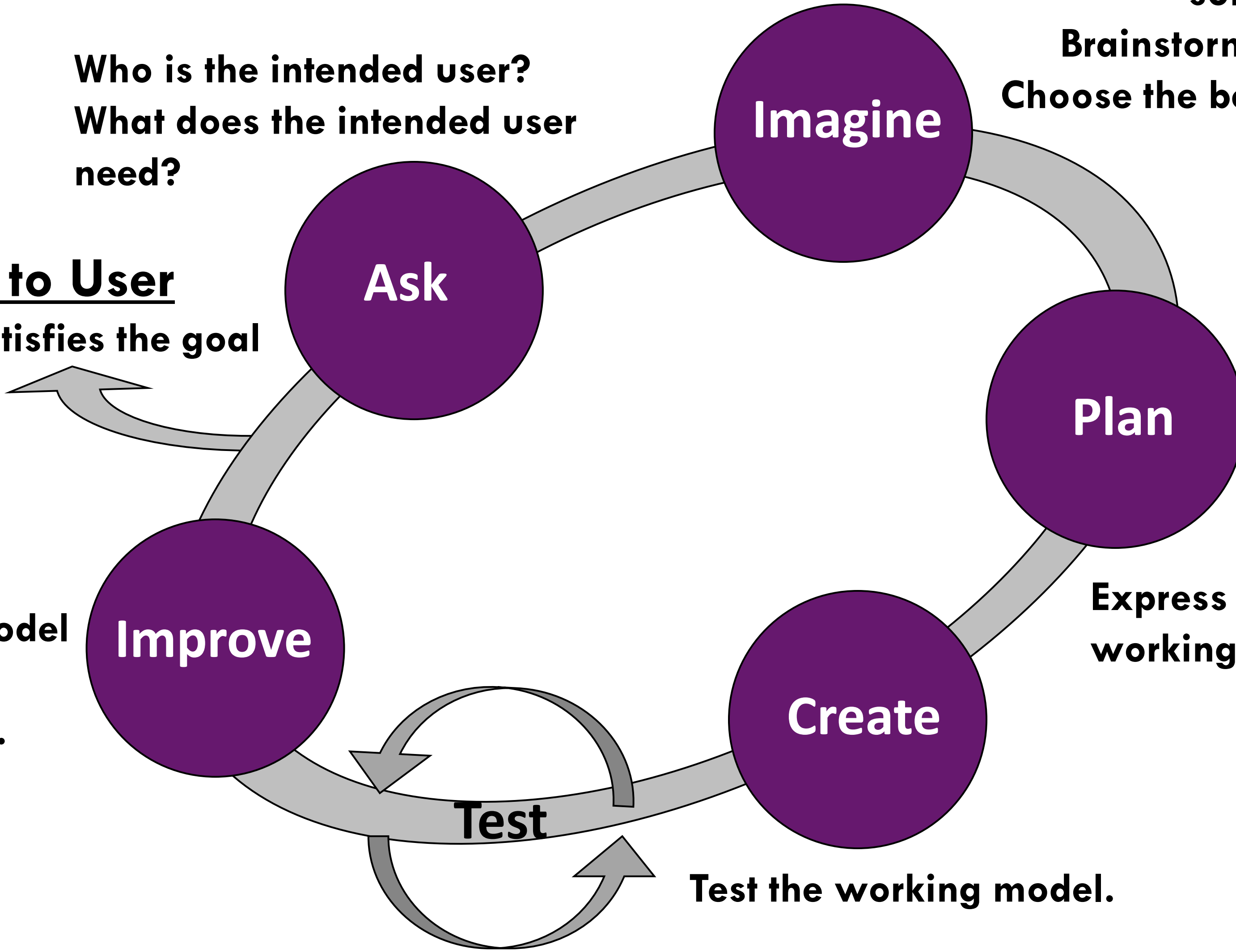
Model Design Process

What could be some solutions?
Brainstorm ideas.
Choose the best one.

Who is the intended user?
What does the intended user need?

Go to User

Model satisfies the goal



Express the working model.

Revise the Working model to make it even better. Test it out!

Test the working model.

A Variety of MEAs

MEA Name	Grade Level	Create a Procedure/Process for…
Concrete	2-3	selecting the best concrete.
Recycle	2-3	sorting items into two recycle bins
Pete's Ice Cream	2-3/4-5	ranking ice cream companies
Sticker	2-4	how to arrange the most stickers on a sheet of paper for cutting
Toothpaste	2-4/5-8	ordering the toothpaste recipes from best to worst
Parachute	3-4	ordering the materials to make a parachute out of from best to worst
Windmill	3-5	selecting the best manufacturer
Water Filters	3-5	ordering the water filters from best to worst
Potato Chip	3-5	ranking shipping companies
Boiler Up	3-6	making a football team schedule
Awesome School	3-6	picking a company to make school lunches
Green Roof	9-10 (Physical Science)	choosing property to buy based on "green" features
Electric Toothbrush	10-12 (Physics)	ordering batteries for electronic toothbrushes

Community Building/Resources: INSPIRE Assessment Center

PURDUE UNIVERSITY

Publications | Projects | Initiatives | Assessment Center | Partners | Community

Teaching Design, Engineering, and Technology Survey (DET)

Average

I. DESCRIPTIVE PROPERTIES:

Purpose:
To assess K-12 teachers' perceptions of engineering and their familiarity with teaching design, engineering, and technology (DET)

Number of Items: 41

Instrument Type:
4-point Likert-scale self-report survey

Scale: 1-4 (1 Strongly Disagree, 4 Strongly Agree)

Administration Time:
N/A

Sample Item: N/A

II. PSYCHOMETRIC PROPERTIES:

Validity Evidence: High

Source:
Yasar, S., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. Journal of Engineering Education, 95(3), 205-216.

https://engineering.purdue.edu/Inspire_center

Prof. Senay Purzer

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Journal of Pre-College Engineering Education Research (J-PEER)

INSPIRE!

PURDUE ENGINEERING

PURDUE ENGINEERING EDUCATION

Editors

OUR VISION

To create an engineering-literate society through preeminence in P-12 engineering education research and scholarship.

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A COMMITMENT TO AN ENGINEERING-LITERATE SOCIETY

The graduates of today and tomorrow enter into a world that requires them to be engineering--literate and technologically savvy. The integration of engineering education in grades P-12 will better arm students with essential tools and skills to enter into the workforce or postsecondary education. Additionally, due to a 20 percent slip in the number of engineers graduating from U.S. institutions and with more than half of the U.S. workforce in the sciences and engineering approaching retirement age, the need for a diverse group of students interested in and prepared to study engineering in college is ever growing.

It is essential that young engineers from the U.S. be involved in the next generation of innovative ideas that support our society's needs. This interest and drive to participate in engineering must be fostered at an early age. J-PEER is dedicated to addressing the downward trends in engineering interest, preparedness, and representation; to transforming P-12 education to include engineering; to preparing a globally competitive engineering workforce; and ultimately to creating a society of engineering--literate citizens.

Questions?

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