2017 ANNUAL CONFERENCE & EXPOSITION

Closing the Gap: Industry Perspectives on Undergraduate Preparation for Practice

Moderator: Erica Messinger
Keysight Technologies

ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Speakers

- Thomas J Perry, P.E., Director, Engineering Education (ret.), ASME
  - *"ASME Vision 2030 – the Voices of 2,500 Industry Supervisors, Early-career Engineers and ME Department Heads on the Practice-readiness of Entry-level ME's – and Changes that are Happening in ME Degree Programs"*
- Mark Cousino, Director Functional Learning and Technology, The Boeing Company
  - *"Challenges in Big Data Learning Analytics for Workforce Learning"*
- Dr. Alice Squires, International Council on Systems Engineering (INCOSE), Associate Professor, Washington State University
  - *"Bridging the Gap Between Engineering Education and Practice with Systems Savvy Engineers"*
- Dan Sayre, Executive Marketing Manager, John Wiley & Sons, Inc.
  - *"Three Models for 21st Century Engineers –or– Knowledge, Skills, Attributes and how they grow"*

ASME Vision 2030 – the Voices of 2,500 Industry Supervisors, Early-career Engineers and ME Department Heads on the Practice-readiness of Entry-level ME's – and Changes that are Happening in ME Degree Programs

Speaker: Thomas J Perry, P.E.

American Society of Mechanical Engineers

ASME… *at a Glance*

130,000+ members in **> 150** countries

500+ standards in **> 100** countries

35+ major conferences annually

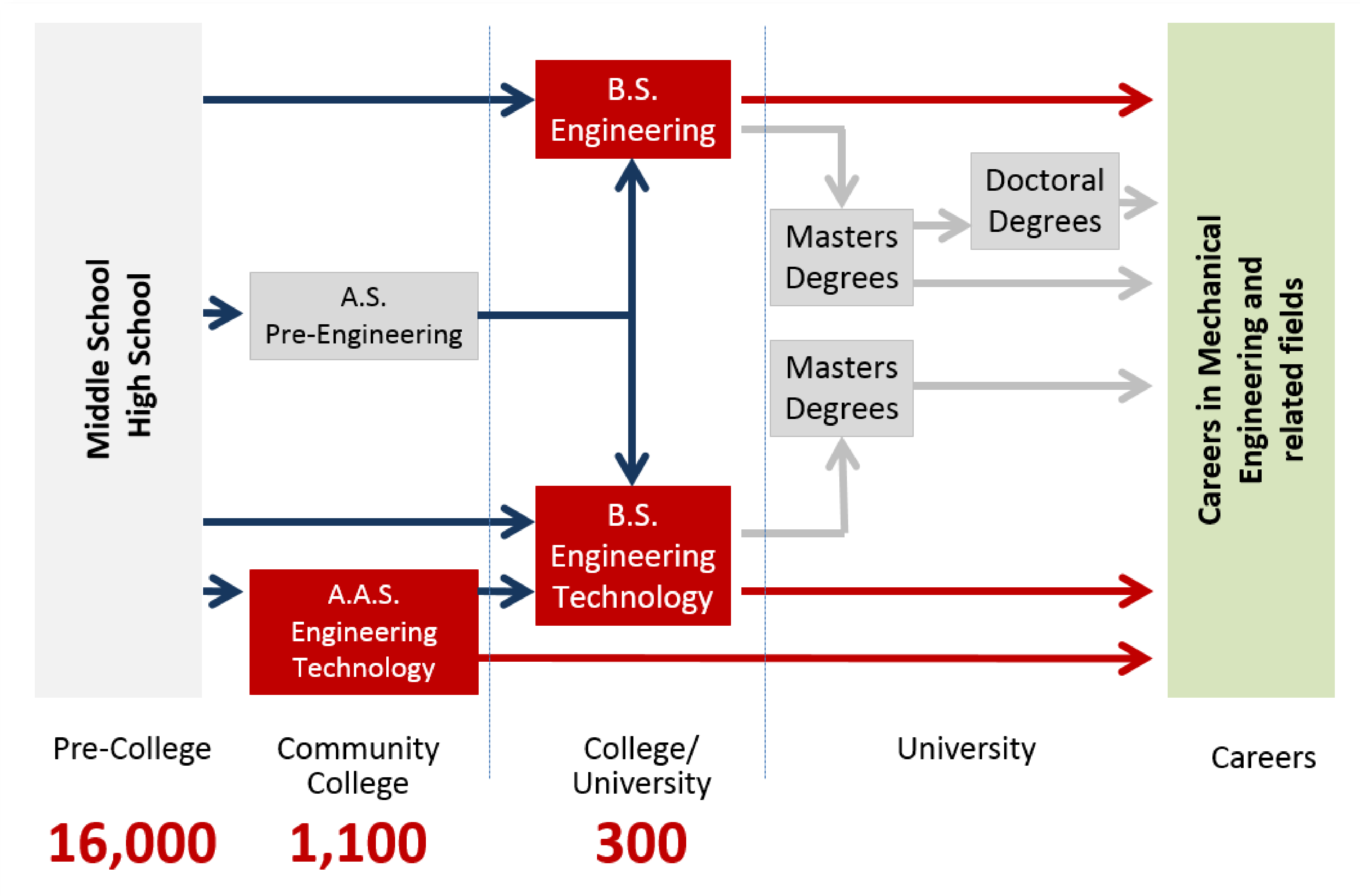
180 technical courses/seminars for engineers

460 ME/MET degree programs accredited through ABET

Digital collection of technical papers

Offices in China, India, Belgium & US (New York - New Jersey - Washington, DC - Houston)

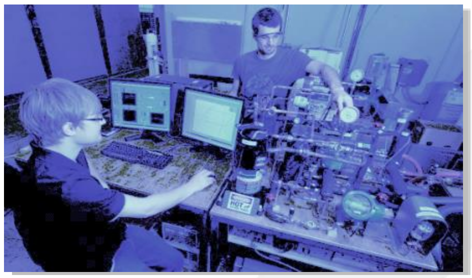
Pathways to Engineering Careers

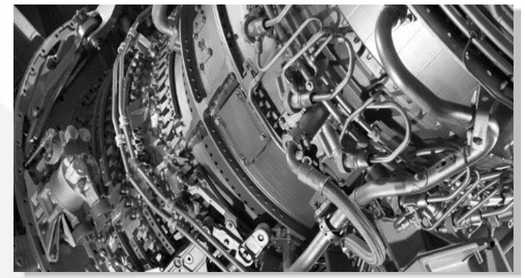


COLUMBUS OHIO WHERE ENGINEERING EDUCATION TAKES FLIGHT FROM P-12 THROUGH LIFE ASEE 2017

College of Engineering

Asymmetric Forces





Innovation

Research Intensive

Practice Intensive

Engineering Fundamentals

Govt $

?

ASME Vision2030 Mechanical Engineering Education

go.asme.org/v2030

ASME Engineering Education
Vision 2030

~2,600 VOICES

1,400
Industry Managers

1,100
Early-career Engineers

80 ME Department Heads

ASME Engineering Education **Vision 2030**

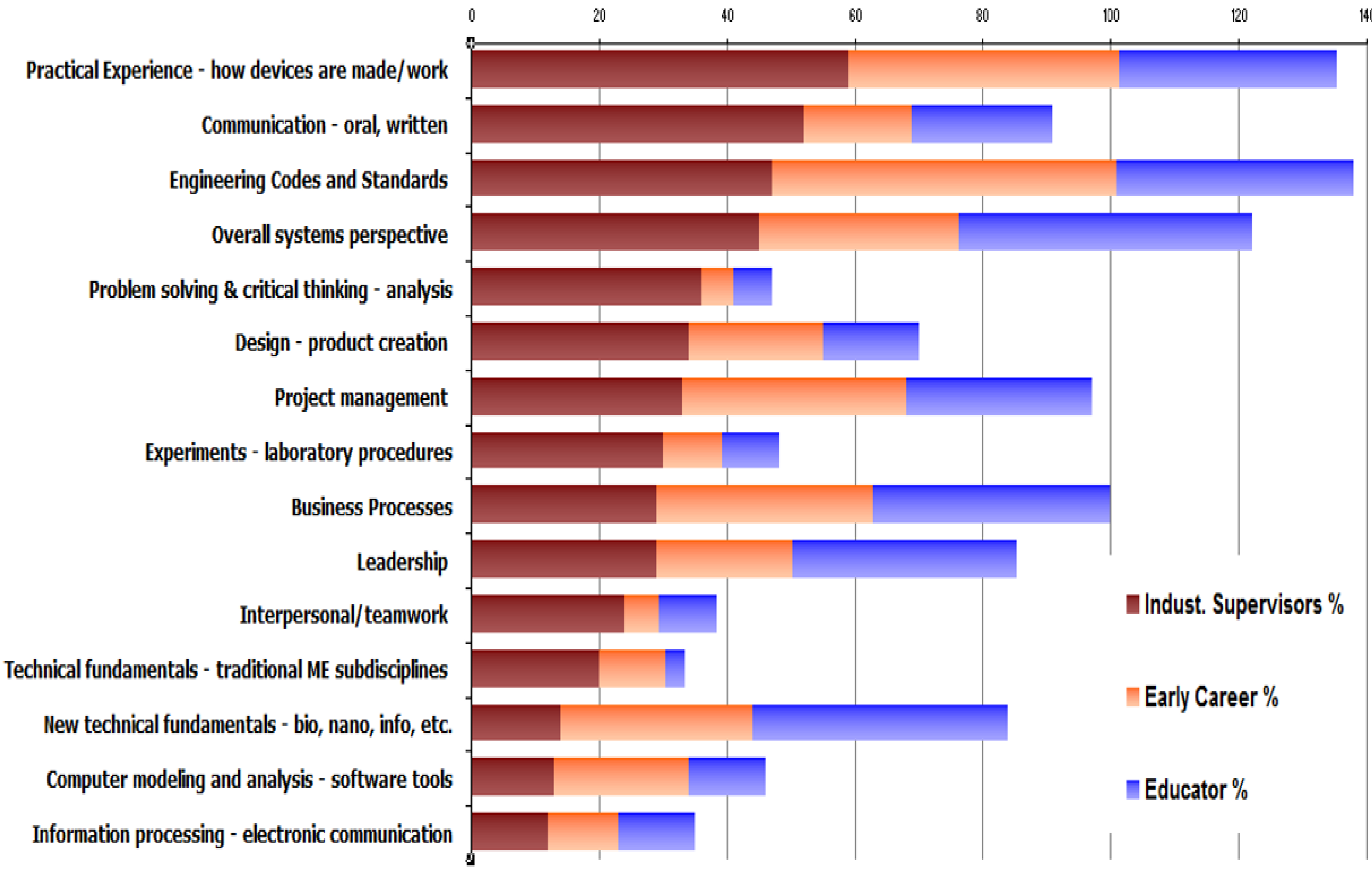
- **Practical Experience**
- **Communications Skills**
- **Industry Codes & Standards**
- **Overall Systems Perspective**
- **Problem Solving, Critical Thinking, Analysis**
- **Design** (Product Creation)
- **Project Management**
- **Experiments – Laboratory Procedures**
- **Business Processes**
- **Leadership**
- **Interpersonal/Teamwork**
- **Technical Fundamentals** (Traditional ME Sub-Disciplines)
- **New Technical Fundamentals** (Bio, Nano, Info)
- **Computer Modeling/Analysis, Software Tools**
- **Information Processing/Electronic Communications**

go.asme.org/v2030

ASME Engineering Education **Vision 2030**

- ❑ **Not Important for Entry Level**
- ❑ **Weak – But not an entry-level concern**
- ❑ **Weak – Needs Strengthening**
- ❑ **Sufficient – No Concerns**
- ❑ **Strong**
- ❑ **Strong – but needs even more emphasis**

Where new BSME Graduates are considered weak and need strengthening



ASME Engineering Education **Vision 2030**

1) Richer and more extensive practice-based engineering experience for students
2) New balance of faculty research/industry practice skills in ME programs
3) Greater cultivation of collaborative inclusion, diversity, creativity, and innovation among students and faculty
4) Development of students' professional, and communication skills to higher standards
5) Increased flexibility in ME Programs

go.asme.org/v2030

ASME Engineering Education
Vision 2030

2016-2017 Impact/Implementation Preliminary Study

(88 ME Programs)

go.asme.org/v2030

ASME Engineering Education **Vision 2030**

What we've learned so far…

88 ME programs responding

52% have seen reports publications or data referencing V2030

44% of those have used V2030 information to work with faculty on curriculum changes

"Expanded engineering, business, and social science electives for ME students. Actively stress broad impact of engineering on society. ME programs responding."

"I have used that data to try to argue for more resources from the central administration"

"Increased use of projects, codes and standards, Systems Engrg approach"

"It has been used primarily with advisory boards and for overall planning. It has supported the shift to more professional skills focus."

go.asme.org/v2030

ASME Engineering Education
Vision 2030

"We are basing our new curriculum in ME off of Vision 2030."

"Drove flexible curriculum change .....highly successful!"

"In part, due to V2030, we were able to develop a more flexible curriculum (9 credits of open/professional electives replaced 9 credits of technical electives)"

"We have strengthened the "design spine" aspect of our curriculum, and have revised several courses to have a more comprehensive design-test-build component to them."

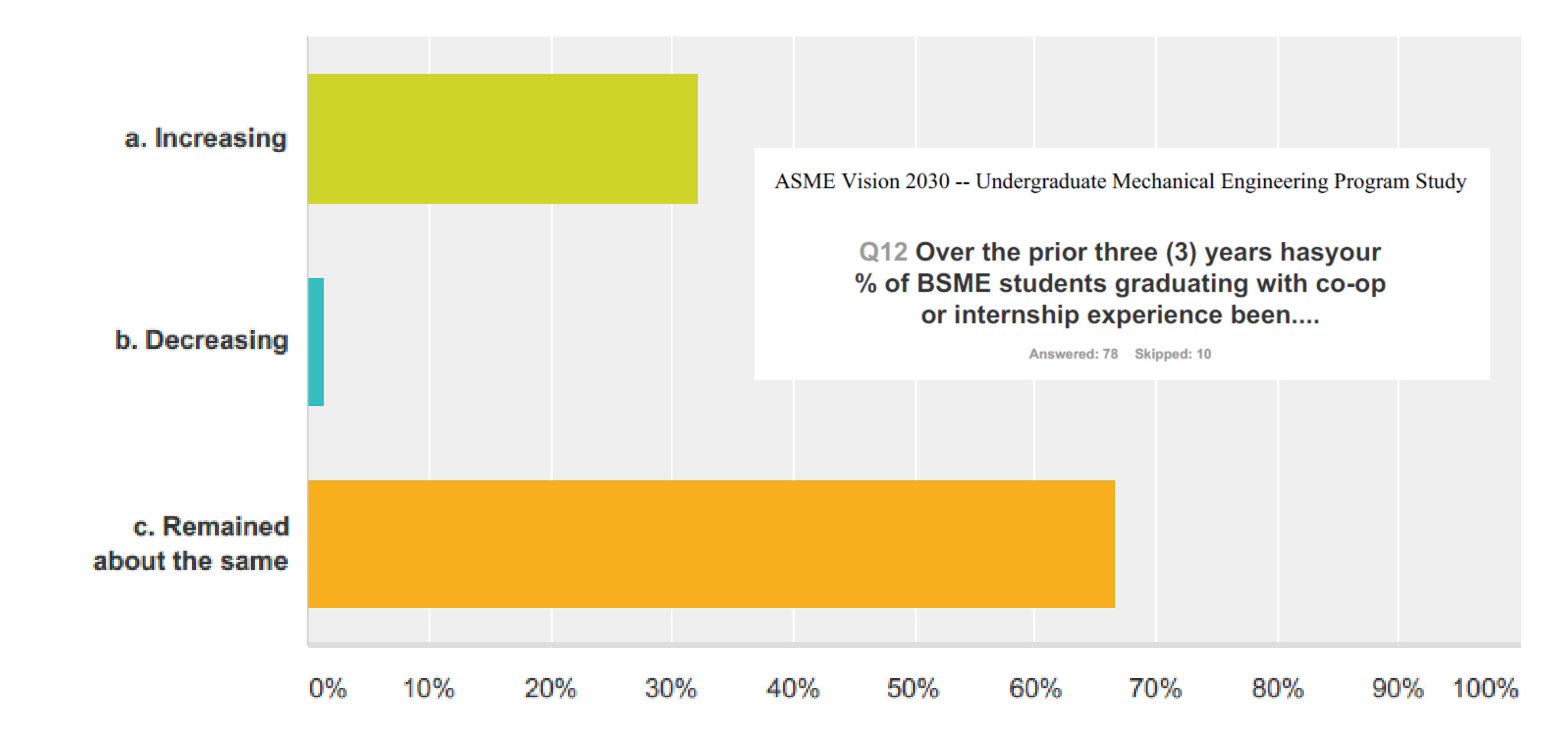
go.asme.org/v2030

ASME Engineering Education
Vision 2030

Q10 For required courses in your undergraduate curriculum, please indicate which year(s) students engage in the following:

	Year 1	Year 2	Year 3	Year 4
a. Simulation	**32.05%** 25	**39.74%** 31	**70.51%** 55	**69.23%** 54
b. Design-Build-Test	**60.26%** 47	**35.90%** 28	**44.87%** 35	**85.90%** 67
c. Use of industry Codes & Standards	**8.86%** 7	**10.13%** 8	**40.51%** 32	**79.75%** 63
d. Required Collaborative Team-based Problem Solving	**70.89%** 56	**49.37%** 39	**64.56%** 51	**87.34%** 69
e. Innovation/Creativity: Opportunities for Discovery-Based Learning	**44.16%** 34	**41.56%** 32	**53.25%** 41	**66.23%** 51

ASME Engineering Education
Vision 2030



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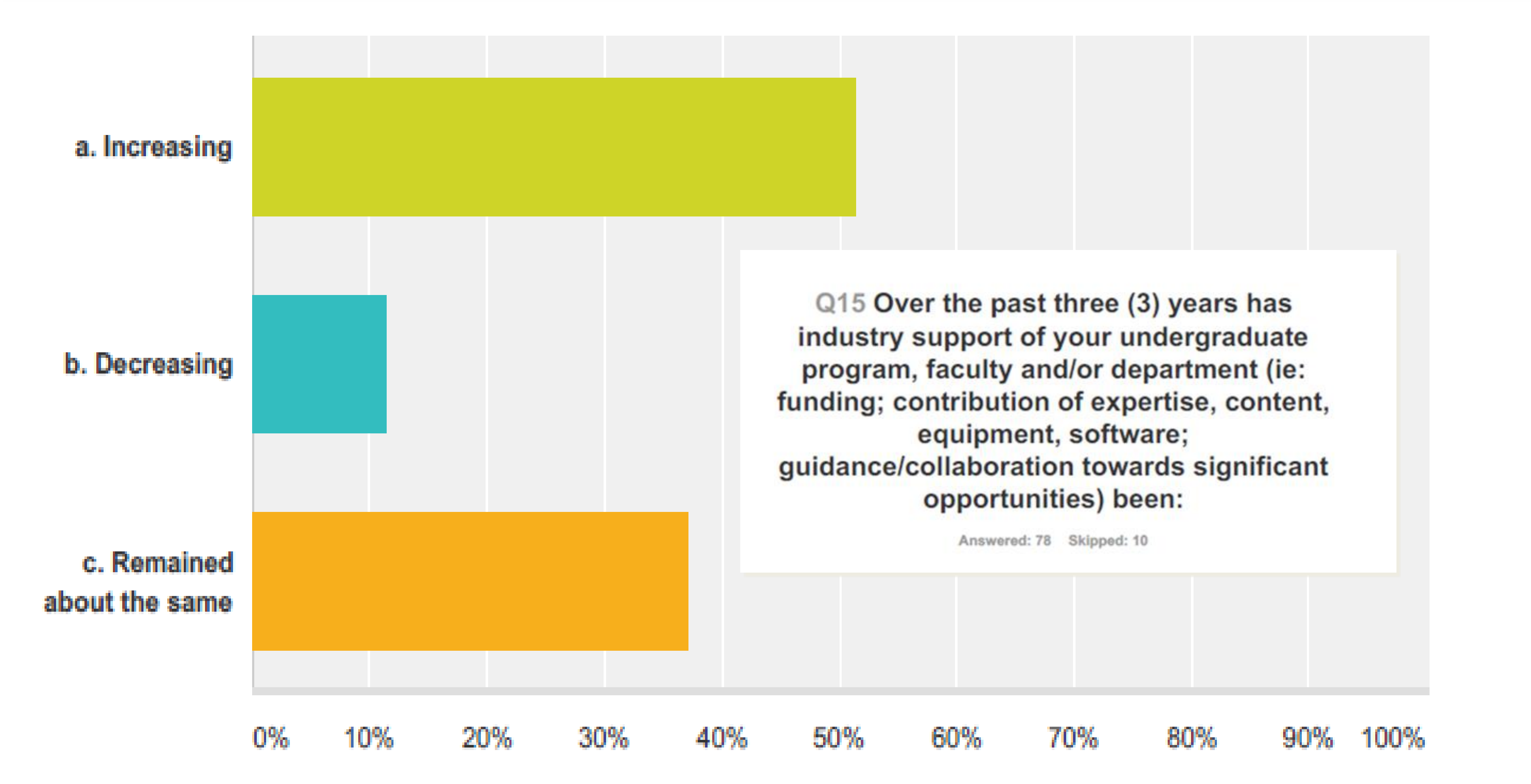
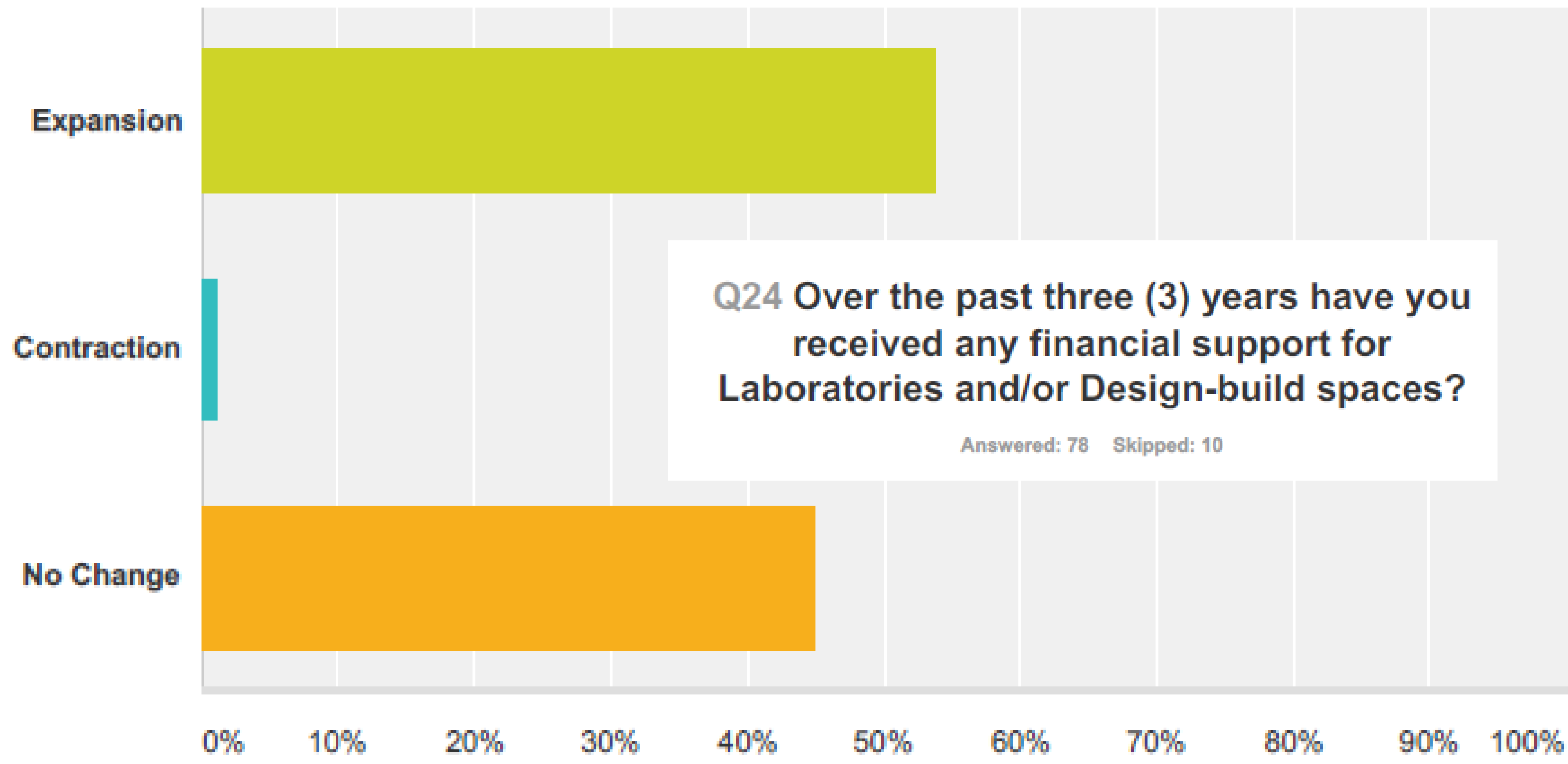
ASME Engineering Education **Vision 2030**

Industry Support



ASME Engineering Education **Vision 2030**



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ASME Engineering Education
Vision 2030

Professors of Practice

57% employ professors of practice

17% Do not, but plan to do so over the next 3 years

26% have no plans to employ Professors of Practice

67% of Professors of Practice were hired predominantly for their industry experience

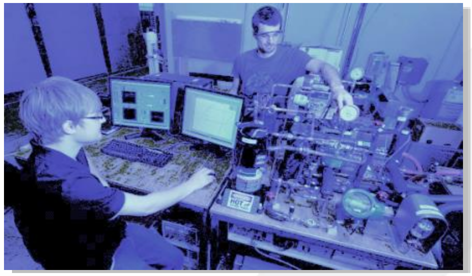
67% Are funded from operating Budgets

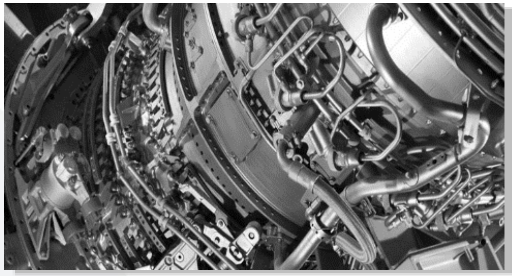
30% Funded from combined operating and other sources

3% are industry-endowed positions

College of Engineering

Asymmetric Forces





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Challenges in Big Data Learning Analytics for Workforce Learning

Speaker: Mark Cousino
The Boeing Company

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WHERE ENGINEERING EDUCATION TAKES FLIGHT FROM K-12 THROUGH LIFE
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2017 ANNUAL CONFERENCE & EXPOSITION

Bridging the Gap Between Engineering Education and Practice with Systems Savvy Engineers

Speaker: Dr. Alice Squires
International Council on Systems Engineering
Washington State University

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AMERICAN SOCIETY FOR ENGINEERING EDUCATION

The International Council on Systems Engineering (INCOSE)

- Not-for-profit membership organization founded in 1990 to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems
  - > 100 corporate members
  - > 13,000 members around the globe
  - > 30 countries, 70+ local chapters
- Flagship products include:
  - Systems Engineering Body of Knowledge (SEBoK): www.sebokwiki.org
  - A World in Motion: Systems Engineering Vision 2025:http://www.incose.org/docs/default-source/aboutse/se-vision-2025.pdf
  - Systems Engineering Handbook, 4th Edition (see incose.org)
  - Graduate Reference Curriculum in Systems Engineering (GRCSE) (www.BKCASE.org)
  - World Wide Academic Program Directory (www.incose.org/AboutSE/SEEducation/SEProgramDirectory)

Systems Engineering Imperatives*

- Expanding the APPLICATION of systems engineering across industry domains.
- Embracing and learning from the diversity of systems engineering APPROACHES.
- Applying systems engineering to help shape policy related to SOCIAL AND NATURAL SYSTEMS.
- Expanding the THEORETICAL foundation for systems engineering.
- Advancing the TOOLS and METHODS to address complexity.
- Enhancing EDUCATION and TRAINING to grow a SYSTEMS ENGINEERING WORKFORCE that meets the increasing demand.

*INCOSE (2014), "A World in Motion: Systems Engineering Vision 2025"

Why do we need Systems Engineering Knowledge, Skills, and Abilities?

Human needs have hardly changed over the centuries. Societal needs are similar throughout the world, and systems need to respond to such needs.

INCOSE (2014), “A World in Motion: Systems Engineering Vision 2025”

Top 10 skills

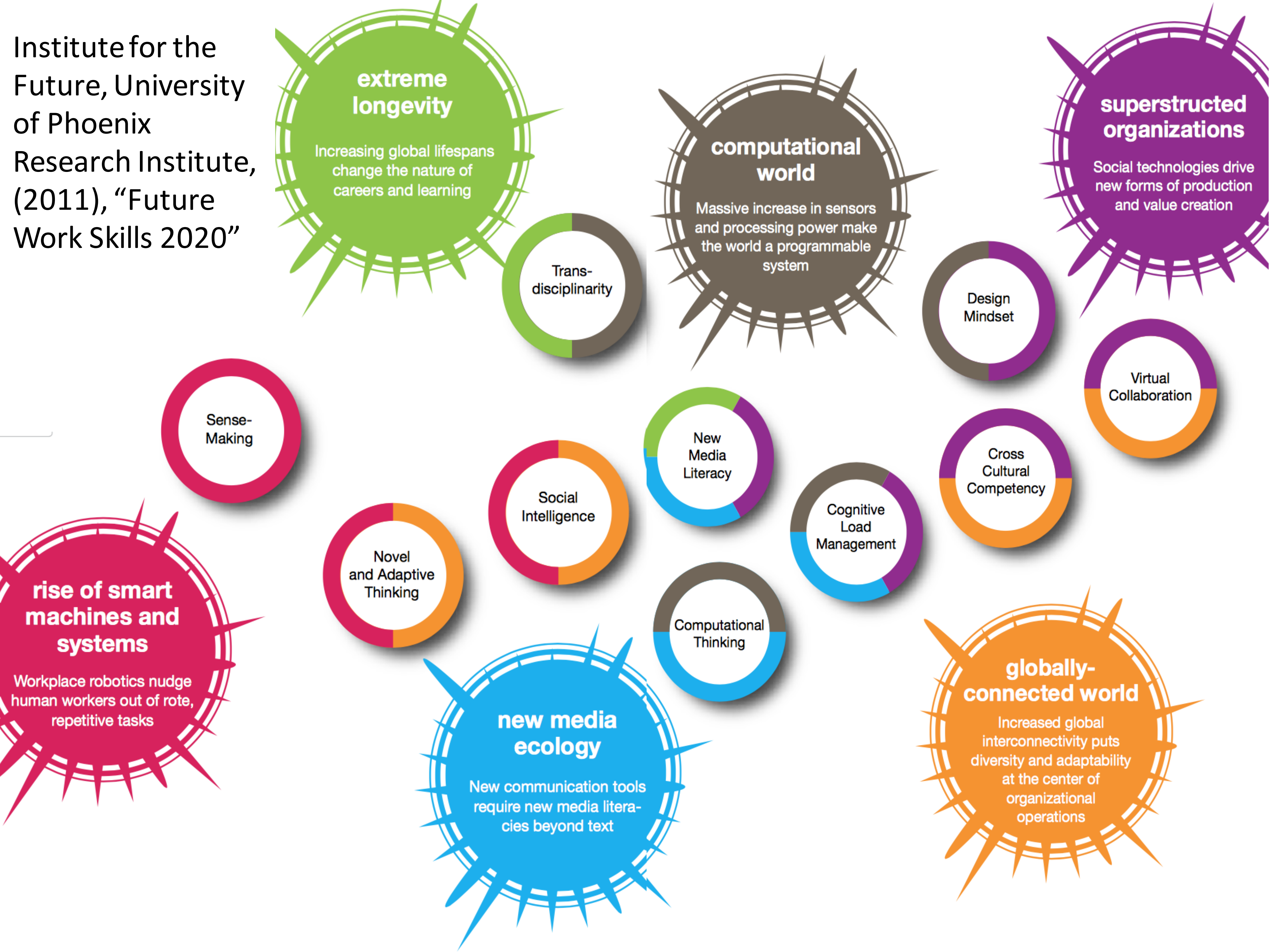
in 2020

1. Complex Problem Solving
2. Critical Thinking
3. Creativity
4. People Management
5. Coordinating with Others
6. Emotional Intelligence
7. Judgment and Decision Making
8. Service Orientation
9. Negotiation
10. Cognitive Flexibility

in 2015

1. Complex Problem Solving
2. Coordinating with Others
3. People Management
4. Critical Thinking
5. Negotiation
6. ~~Quality Control~~
7. Service Orientation
8. Judgment and Decision Making
9. ~~Active Listening~~
10. Creativity

Institute for the Future, University of Phoenix Research Institute, (2011), “Future Work Skills 2020”



TEN SKILLS FOR THE FUTURE WORKFORCE

1 SENSE-MAKING

DEFINITION: *ability to determine the deeper meaning or significance of what is being expressed*

2 SOCIAL INTELLIGENCE

DEFINITION: *ability to connect to others in a deep and direct way, to sense and stimulate reactions and desired interactions*

3 NOVEL & ADAPTIVE THINKING

DEFINITION: *proficiency at thinking and coming up with solutions and responses beyond that which is rote or rule-based*

4 CROSS-CULTURAL COMPETENCY

DEFINITION: *ability to operate in different cultural settings*

5 COMPUTATIONAL THINKING

DEFINITION: *ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning*

6 NEW-MEDIA LITERACY

DEFINITION: *ability to critically assess and develop content that uses new media forms, and to leverage these media for persuasive communication*

7 TRANSDISCIPLINARITY

DEFINITION: *literacy in and ability to understand concepts across multiple disciplines*

8 DESIGN MINDSET

DEFINITION: *ability to represent and develop tasks and work processes for desired outcomes*

9 COGNITIVE LOAD MANAGEMENT

DEFINITION: *ability to discriminate and filter information for importance, and to understand how to maximize cognitive functioning using a variety of tools and techniques*

10 VIRTUAL COLLABORATION

DEFINITION: *ability to work productively, drive engagement, and demonstrate presence as a member of a virtual team.*

DRIVERS

- extreme longevity
- rise of smart machines and systems
- new media ecology
- computational world
- superstructured organizations
- globally connected world

Institute for the Future, University of Phoenix Research Institute, (2011), “Future Work Skills 2020”

SYSTEMS ENGINEERING IS BROADLY APPLICABLE

- Systems Thinking used by those in many domains & disciplines.
- Systems Engineering is a discipline used by many.

- Systems Engineering is a career for a few.

INCOSE (2014), "A World in Motion: Systems Engineering Vision 2025"

Which Systems Engineering Knowledge, Skills, and Abilities are needed in engineering education?

Four Key Areas Identified

INCOSE Academic Forum 2015

1. Systems Science and Fundamentals: Formal science dealing with the nature of systems; the science "behind" systems engineering.
2. Systems Thinking: Holistic thinking. Critical thinking guided by systems theory.
3. Design and Analysis: The examination of a problem from all aspects and the development of an effective solution.
4. Technical and Project Management: Applying knowledge, skills, tools, and techniques to manage the cost, schedule, and technical aspects of a project to meet the project requirements.

Top 6 KSA Areas
ASEE Workshop 2015

1. Systems Science and Fundamentals
   - a. **Understanding Complexity**
   - b. Systems Theory
   - c. Emergence
   - d. System Patterns (e.g., feedback, cycles, hierarchies)
   - e. System Taxonomies

2. Systems Thinking
   - a. **Interdependencies (interactions, interfaces, relationships) among multi-disciplines**
   - b. **Problem Analysis (goals and objectives, needs statement, requirements elicitation)**
   - c. Total Life-cycle View
   - d. Multiple and holistic perspectives
   - e. System definition, purpose, scoping
   - f. Users / stakeholders
   - g. Context and environment

3. Design and Analysis
   - a. Systems Architecture and Analysis
   - b. **System Modeling**
   - c. **Requirements Analysis**
   - d. **Trade off and decision analysis**
   - e. Dealing with complexity
   - f. Systems Integration
   - g. Verification and Validation
   - h. CONOPS = Concept of Operations
   - i. Design reviews
   - j. -ilities (inc. reliability, availability, maintainability, supportability, producibility, security, safety, usability, affordability, sustainability)

4. Technical and Project Management
   - a. Dealing with Uncertainties and Change
   - b. Risk/opportunities
   - c. Life-cycle models
   - d. Project Planning and Performance
   - e. Configuration management and control
   - f. Requirements Management
   - g. Milestone Reviews (program & technical)

SE KSA Delivery Methods
ASEE Workshop 2015

In support of another main topic within a course

As a specific systems focused module/lecture within a course

As a course related to systems

As a non-capstone project based (eg. case study, lab) course

As a capstone course / senior design project

Bloom's Levels

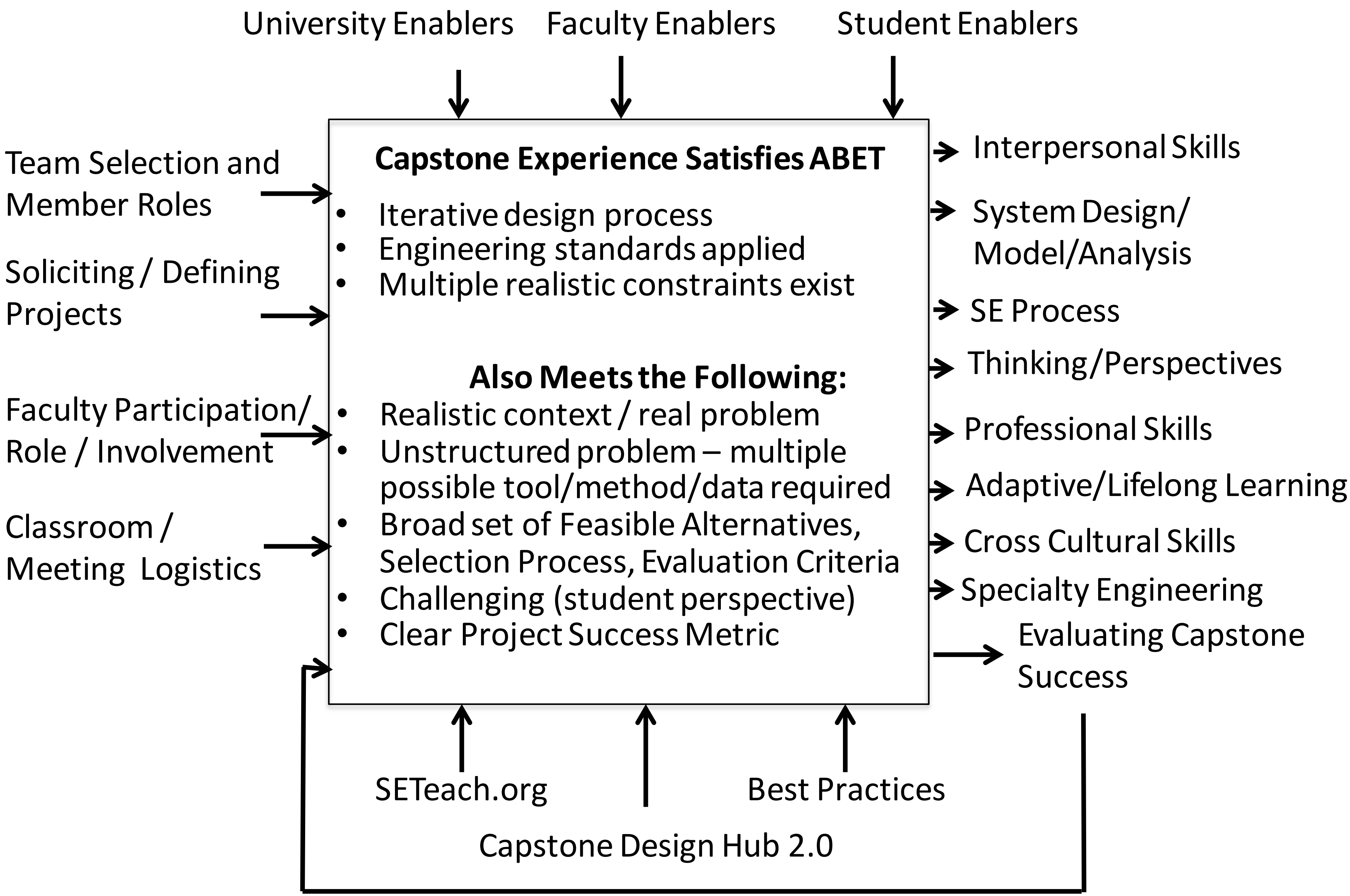
- Remember: The student can recall or remember the information.
- Understand: The student can explain the ideas or concepts to someone else.
- Apply: The student can use the information in a new way.
- Analyze: The student can exam and distinguish between the different parts.
- Evaluate: The student can justify taking a stand or making a decision.
- Create: The student can create a new product or point of view or advance the state of the art.

Results: Bloom's Cognitive Levels
ASEE Workshop 2015

System KSA	Remember	Understand	Apply	Analyze	Evaluate	Create
Group A: 1st/2nd Year						
Top 1: Interdependencies		1	2	1		
Top 2: System Modeling	1	1	1	1		
Top 3: Trade-off & DA			2	2		
Top 4: Problem Analysis			2	2		
Top 5: Reqs Analysis		1	2	1		
Top 6: Und. Complexity		4				
Group B: Class Project/Case Study						
Top 1: Interdependencies		3		1		
Top 2: System Modeling			2	2		
Top 3: Trade-off & DA					4	
Top 4: Problem Analysis			2	1	1	
Top 5: Reqs Analysis			1	2		1
Top 6: Und. Complexity		4				
Group C: Capstone						
Top 1: Interdependencies			1	1	3	1
Top 2: System Modeling			2	2		2
Top 3: Trade-off & DA				2	4	
Top 4: Problem Analysis			1	1	2	2
Top 5: Reqs Analysis			1	2	1	2
Top 6: Und. Complexity		3	1	2		

Integrating SE Knowledge and Skills via Capstone Experience

INCOSE Academic Forum 2016



What's the Problem?

ASEE 2015 Pre-survey Question: Top "Obstacle" Themes

What problems have you faced in teaching systems concepts, or what obstacles prevent you from teaching systems concepts?

1. Faculty need more training and preparation on systems engineering material.
2. There is a perceived lack of value by colleagues and students.
3. Students do not understand the concepts being taught.
4. Systems engineering principles, concepts, and terminology are ambiguous.
5. There is a lack of systems engineering educational material and resources.
6. There is no room in the curriculum.

Potential Obstacles to Systems Engineering as "the Core" of Engineering Education

- Belief in industry and government (in U.S.) that systems engineers are born of decades of experiences and the scars gained along the way
  - *Systems thinking and systems engineering processes can be learned and applied throughout the educational process*
- Belief in academia (in U.S.) that systems engineering is of less value than domain specific disciplines. Educators that were not educated with systems engineering as "the core" see little room in the curriculum, until capstone
  - *Evolving ABET engineering criteria demonstrate importance of systems engineering*
    - *solve complex engineering problems; solutions meet specified needs*
    - *engineering design process definition broadened to include SE concepts*
  - *Change starts with educating the educators and integrating systems concepts into the basic problem solving / engineering design approach*

How Can We Support the Graduation of System Savvy Engineers?

Steps Forward

INCOSE Academic Forum 2016

- Collect/validate evidence that SE-KSA's help in practice
- Foster a broader engagement with industry
- Address misconceptions about SE w/ other vocabulary
- Formulate engineering education research questions; when answers needed
- Identify major stakeholders and form alliances
  - what they value, how we would approach them, …
  - companies, professional societies, ...
- Award champions of SE-KSA integrated into engineering education
- Identify contributing existing funded activities
  - propose additional funding
- Deliver workshops to non-SE faculty to support adoption of SE-KSA into their curriculum
- Share important information on this effort

Three Models for 21st Century Engineers

-or-

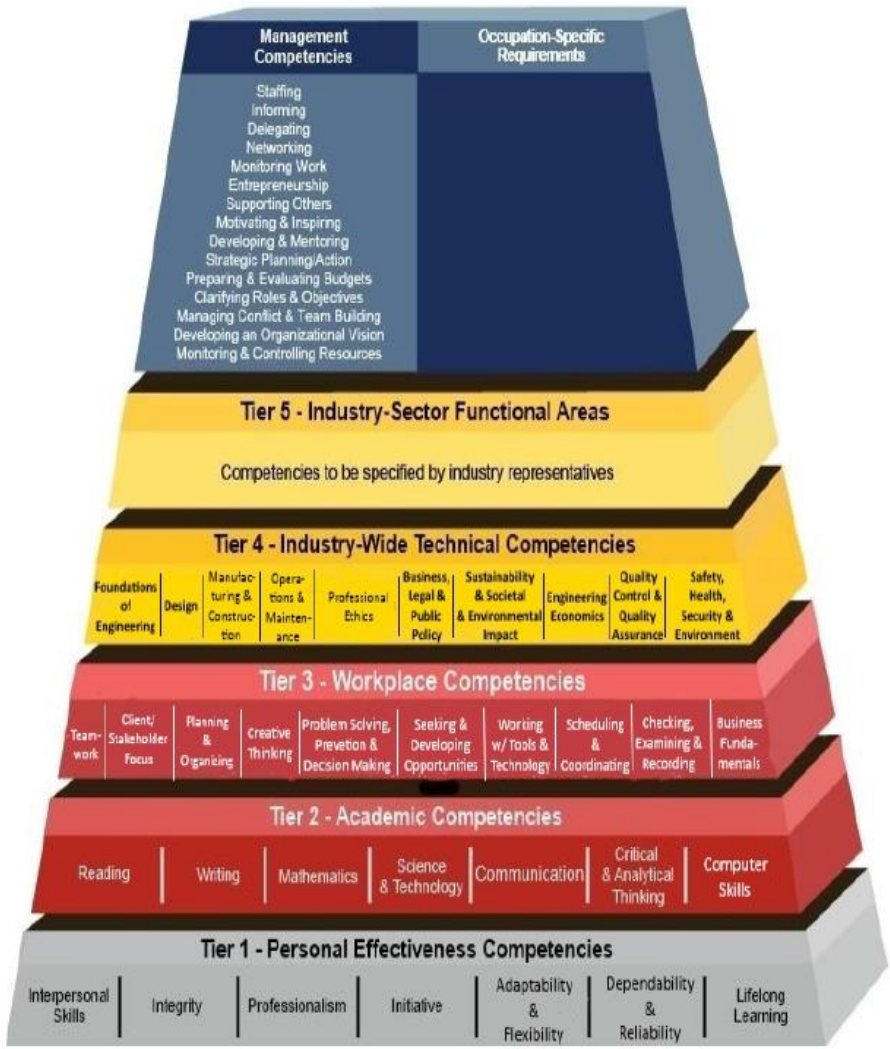
Knowledge, Skills, Attributes and how they grow

Speaker: Dan Sayre
Wiley

1. Engineering Competency Model

- Goal: created to serve as a guide for the development of the engineering workforce. The model outlines the core competencies for advancement and success in the engineering profession.
- Funded by a grant from the United Engineering Foundation, the model was developed by AAES in collaboration with the U.S. Department of Labor's Employment and Training Administration and AAES subject matter experts from education, industry, and private practice.

1. AAES/DoL Competency Model



1. Engineering Competency Model

We need more engineers to harness their capabilities to build a better world.
The **Engineering Competency Model**, depicted below, outlines the core competencies for advancement and success in the engineering profession.

When engineers apply these fundamental skills in their daily work, they **design**, **improve**, and **sustain** the systems and structures we rely on.

2. Attributes of a Global Engineer

- GOAL: "Enhance the employability of engineering graduates and increase the international competitiveness of ASEE's corporate members, so that engineers can effectively live, work, and perform anywhere in the world."
- Project led by ASEE Corporate Member Council
- Principal leadership by Lynn Brown of Boeing and Stephen Hundley of IUPUI

2. Attributes of a Global Engineer

Technical: Engineering-related knowledge, skills, and abilities needed for success

Demonstrates an understanding of engineering, science, and mathematics fundamentals
Demonstrates an understanding of information technology, digital competency, and information literacy
Demonstrates an understanding of stages/phases of product lifecycle (design, prototyping, testing, production, distribution channels, supplier management, etc.)
Demonstrates an understanding of project planning, management, and the impacts of projects on various stakeholder groups (project team members, project sponsor, project client, end-users, etc.)

Professional: Workplace related competencies for global performance

Communicates effectively in a variety of different ways, methods, and media (written, verbal/oral, graphic, listening, electronically, etc.)
Communicates effectively to both technical and non-technical audiences
Maintains a high-level of professional competence
Embraces a commitment to quality principles/standards and continuous improvement
Applies personal and professional judgment in effectively making decisions and managing risks

2. Attributes of a Global Engineer

***Personal:* Individual characteristics needed for global flexibility**

Possesses the ability to think both critically and creatively
Possesses the ability to think both individually and cooperatively
Maintains a positive self-image and possesses positive self-confidence
Shows initiative and demonstrates a willingness to learn

***Interpersonal:* Skills and perspectives to work on interdependent global teams**

Functions effectively on a team (understands team goals, contributes effectively to team work, supports team decisions, respects team members, etc.)
Mentors or helps others accomplish goals/tasks

***Cross-cultural:* Society and cultural understanding to embrace diverse viewpoints**

Demonstrates an understanding of political, social, and economic perspectives
Demonstrates an understanding of the ethical and business norms and applies norms effectively in a given context (organization, industry, country, etc.)
Possesses an international/global perspective
Possesses fluency in at least two languages
Embraces an interdisciplinary/multidisciplinary perspective

2. Attributes of a Global Engineer

Communicates effectively in a variety of different ways, methods, and media

Possesses the ability to think both **critically and creatively**

Shows **initiative** and demonstrates a willingness to learn

Functions effectively on a **team**

Possesses the ability to think both **individually and cooperatively**

Demonstrates an understanding of engineering, science, and mathematics **fundamentals**

Demonstrates an understanding of **information technology, digital competency, and information literacy**

Maintains a **positive self-image** and possesses positive **self-confidence**

3. Transforming Undergraduate Education in Engineering

- Goal: ensure that engineering graduates possess the necessary **knowledge, skills, and abilities** to meet the increasing challenge of global competitiveness.
- Supported by the National Science Foundation, TUEE is a multiphase initiative that seeks to address this need by identifying the critical components of **engineering curricula, pedagogy, and educational culture** required to engage all students in the engineering enterprise and enhance their undergraduate experience.

3. Transforming Undergraduate Education in Engineering

Phase 1 assessed **industry** needs - identifying a core set of knowledge, skills, and professional qualities that will help future engineers succeed in a dynamic, rapidly changing field.

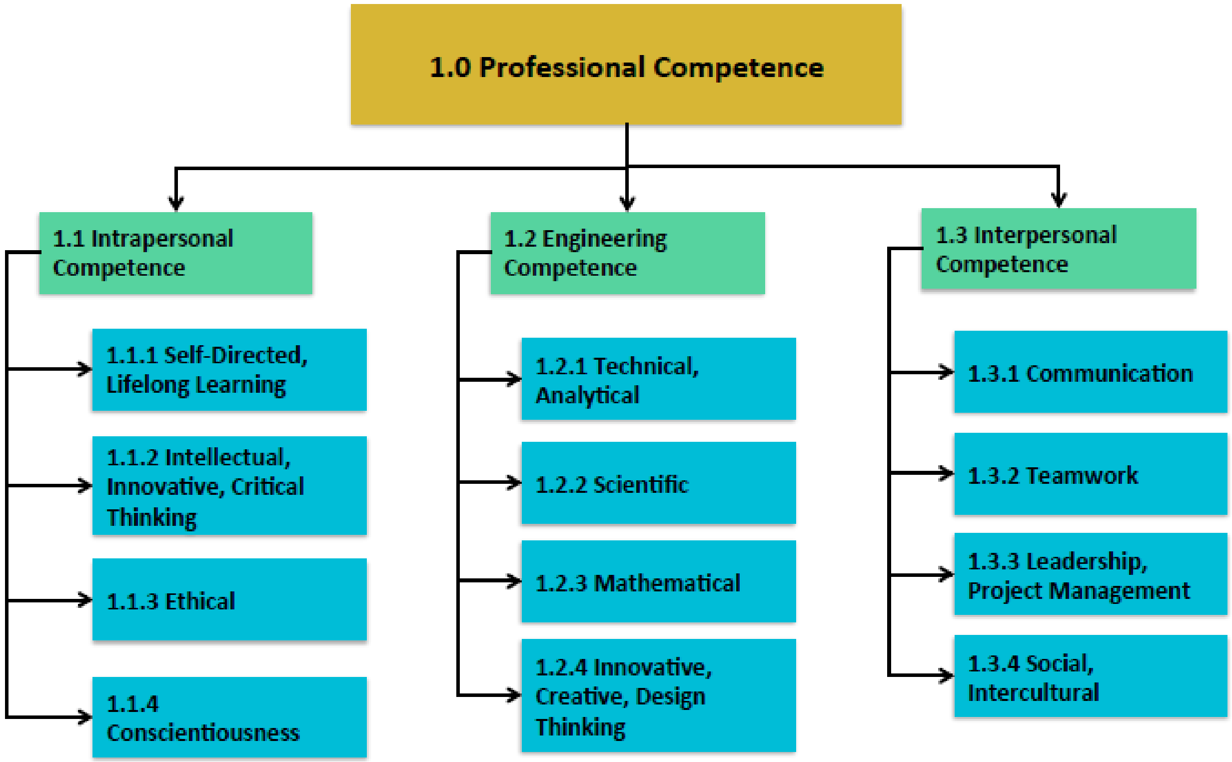
Phase 2 invited **students** to share their views on the strengths and gaps of the current curricular structure and to discuss opportunities to improve their preparation in the core areas identified by industry.

Phase 3 addressed the chronic problem of low **female** participation in undergraduate engineering programs to develop and refine an action agenda.

Phase 4 focused on implementation and the role that **professional societies** (including ASEE) can play.

3. Transforming Undergraduate Education in Engineering

TUEE Competency Map



OVERALL COMPETENCY MAP
Working Draft 16 April 2017

Courtesy of Russ Korte

KSAs – how they grow

- Curricular – course work, projects, presentations, design teams, mentoring, TA …
- Co-curricular – competitions, internships, co-ops ….
- Extra-curricular – volunteering, society chapters, athletics, travel, arts …