

Center for the Advancement of Engineering Education: An Overview of Accomplishments To Date

2007 NAE/CASEE Dane and Mary Louise Miller
SYMPOSIUM



Cynthia J. Atman, Director



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Center for the Advancement of Engineering Education (CAEE)

- Institutions

- Colorado School of Mines
- Howard University
- Stanford University
- University of Minnesota
- University of Washington (Lead)

- Leadership team

- Robin Adams, Cindy Atman, Lorraine Fleming, Larry Leifer, Ron Miller, Barbara Olds, Sheri Sheppard, Karl Smith, Ruth Streveler, Reed Stevens, and Jennifer Turns

American Society for Engineering Education ASEE

Educational Research & Methods ERM

Accreditation Board for Engineering & Technology ABET

EC2000

Nat'l Science Foundation NSF

EEC division

Nat'l Academy of Engr. NAE

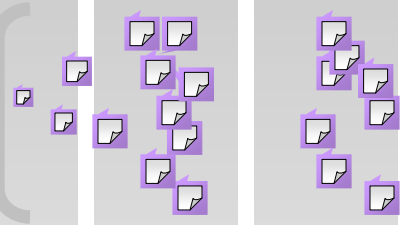
Engr. Ed. Cmte

Gordon Prize

Mann Report

Wickenden Report

publications



organizations

VanTH-ERC

CASEE

NSF Engr. Education Coalitions

CAEE

CIRTL

NCETE

Leonhard Center

CELT

CEE

Engr. Ed. Ctrs

NCEER

Purdue U.

VA Tech

UT St. U.

CO St. U.

Clemson U.

Where we are today in the engineering education community

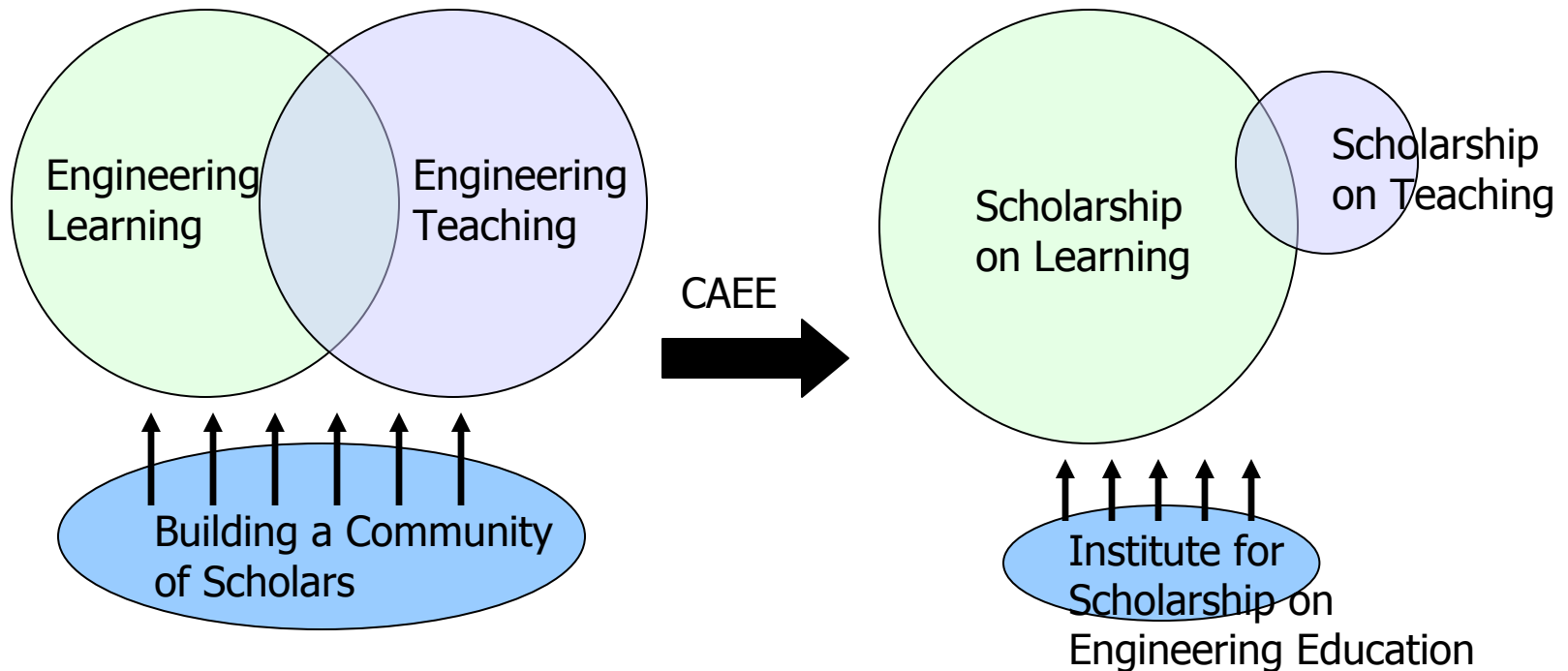
CAEE Goals

- Understand and enhance the engineering student learning experience
- Integrate the needs of diverse faculty and diverse students into engineering education
- Strengthen the engineering education research base
- Expand the community of leaders in engineering education
- Promote effective teaching for current and future faculty

Center for the Advancement of Engineering Education (CAEE)

- **Scholarship on Learning Engineering** (Sheppard)
 - Research on the engineering student experience
 - Academic Pathways Study (APS)
- **Scholarship on Teaching Engineering** (Turns)
 - Research on engineering teaching decision making and knowledge acquisition
- **Institute for Scholarship on Engineering Education** (Adams)
 - Building the engineering education research community
 - Year-long Institutes at UW, Stanford, Howard

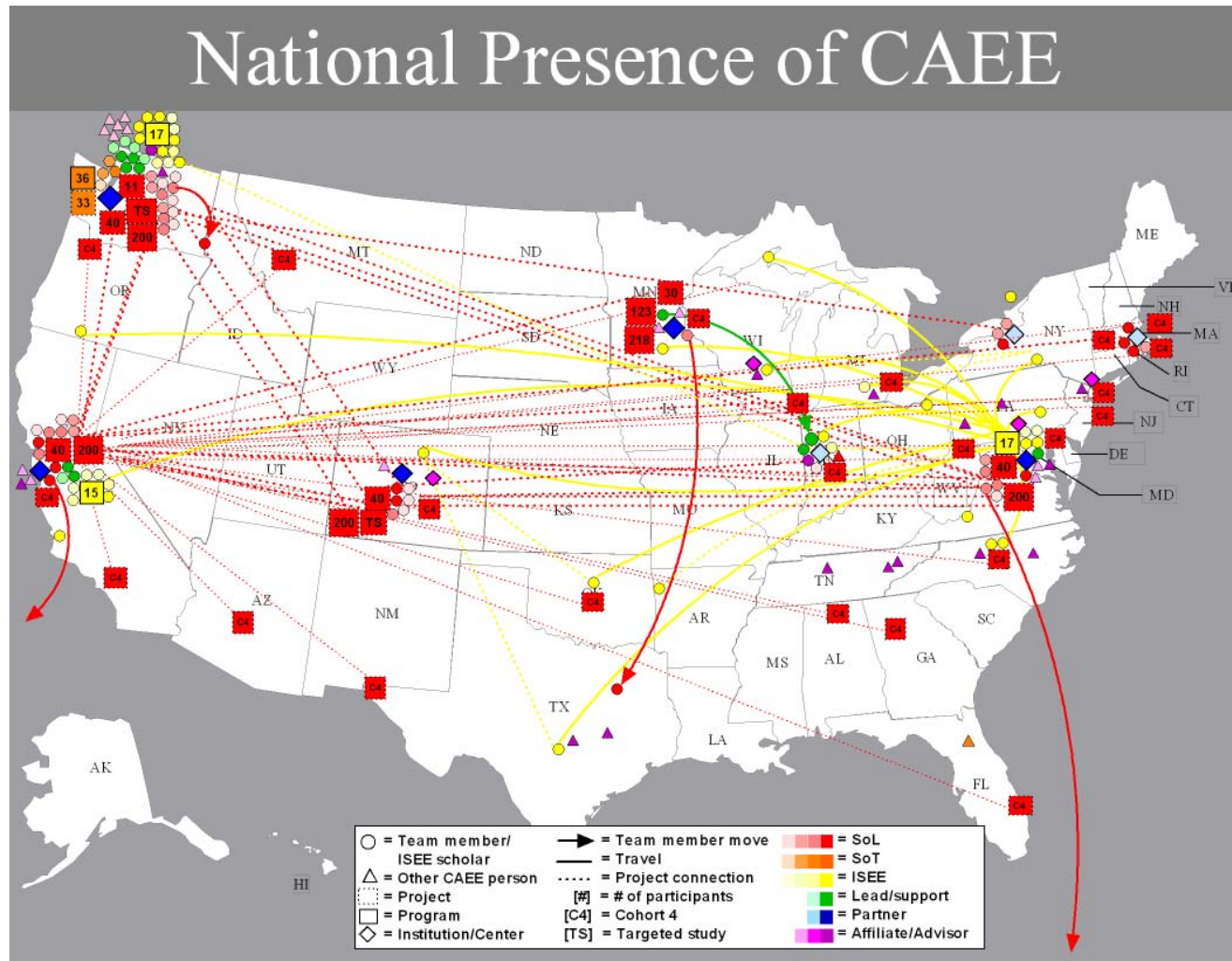
Engineering Education



Where We Are Today – The CAEE Team

- CAEE team today:
 - 52 faculty, research associates, graduate students and staff
 - 12 undergraduates
- 22 graduate and 28 undergraduate students involved in CAEE research since 2003
- Team members now at Purdue U., Olin College of Engineering, U. of Rochester, U. of the Virgin Islands, U. Texas at Tyler

CAEE's Activity May 2006 – Sept. 2007



Today's Agenda

→ Scholarship on Learning

→ APS

- Scholarship on Teaching
 - SEED
- Institute for Scholarship on Engineering Education
- Summary

Scholarship on Learning Team

- Academic Pathways Study
 - Sheri Sheppard, Lead; Daniel Amos, Cindy Atman, Tori Bailey, Özgür Eris, Debbie Chachra, Helen Chen, Krista Donaldson, Kimarie Engerman, Lorraine Fleming, Lari Garrison, Andy Jocuns, Marcus Jones, Deborah Kilgore, Russ Korte, Sislana Ledbetter, Heidi Loshbaugh, Dennis Lund, Janice McCain, Ron Miller, Andrew Morozov, Karl Smith, Reed Stevens, Ruth Streveler, George Toye, Dawn Williams, Ken Yasuhara
- Targeted Studies *

- Phil Bell, Ruth Streveler, Ron Miller, Reed Stevens, Leads; Daniel Amos, Andy Jocuns

Academic Pathways Study (APS)

Sheppard (Lead), Atman, Fleming, Miller, Smith, Stevens, Streveler

- Large scale, multi-method, longitudinal study of undergraduate engineering students
- Three cohorts of students from four very different undergraduate engineering programs and a group of early career engineers
- *From a student's perspective...*

APS Institution Descriptions

- **Coleman University**: medium-sized, private university on the West Coast
- **Mountain Technical Institute**: public university specializing in teaching engineering and technology
- **Oliver University**: private, historically Black, mid-Atlantic institution
- **University of West State**: large, public university in the Northwest US

APS Research Questions

Skills

- How do students' engineering skills and knowledge develop and/or **change over time**?

Identity

- How do pre/engineering students identify themselves?
- How do these students come to **identify themselves as engineers**?
- How do student appreciation, confidence, and commitment to engineering change as they navigate their education?
- What communities do engineering students belong to?
- How does belonging to a community contribute to their identity?

Education

- How do pre/engineering students **navigate their educations**?
- What elements of students' engineering educations contribute to changes observed in their skills and identity?
- What do students find difficult and how do they deal with the difficulties they face?

APS Research Methods

- Surveys
- Structured interviews
- Semi-structured interviews, ethnographic observations
- Engineering “thinking and doing” tasks
- Academic transcript evaluation
- Exit interviews

Assessment of Research Questions By Methodology

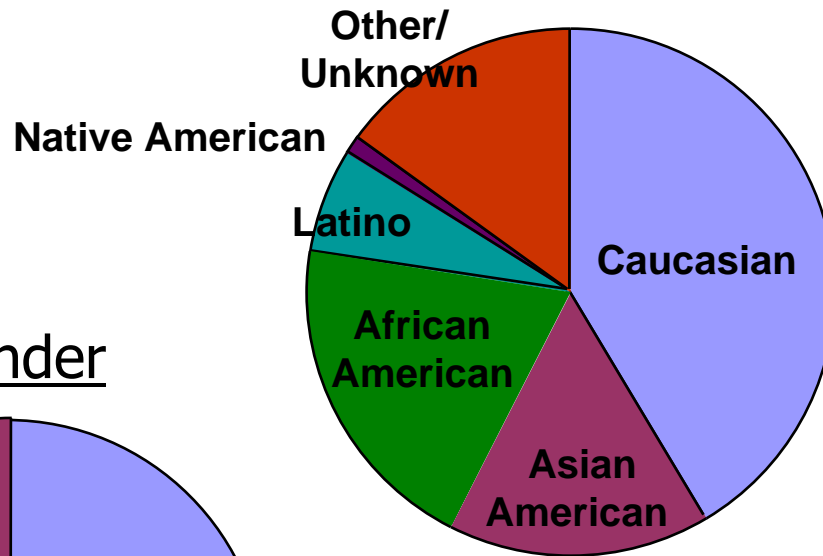
	Ethnography w/Semi- structured Interviews	Structured Interviews	Engineering Design Tasks	Surveys (PIE, APPLE)
Skills	✓	✓ ✓	✓ ✓ ✓	✓
Identity	✓ ✓ ✓	✓ ✓	✓	✓ ✓
Education	✓ ✓	✓ ✓	✓	✓ ✓ ✓

Overview of the Research Participants

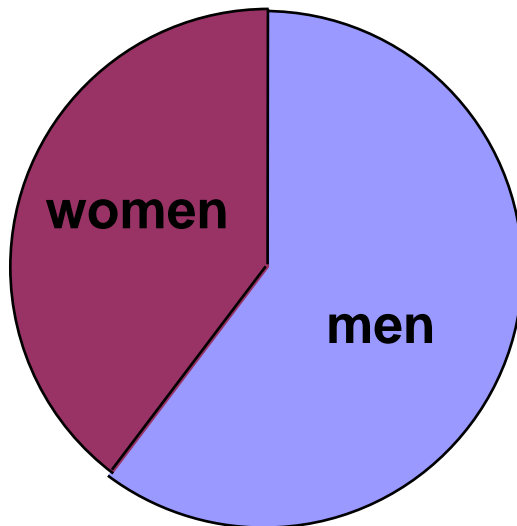
- **Cohort 1***: 160 undergraduate engineering students on the 4 APS campuses followed for 4 academic years
 - **Cohort 3***: 800+ undergraduate engineering students on the 4 APS campuses
 - **Cohort 4**: Large future sample of undergraduate engineering students at 20 universities across the U.S.
-
- **Cohort 2***: 40+ early career engineers
-
- **Cohort 1'***: 341 undergraduate engineering students across all academic years at University of Minnesota

Cohort 1 Make-up: 160 (40 students per school), Fall 2003

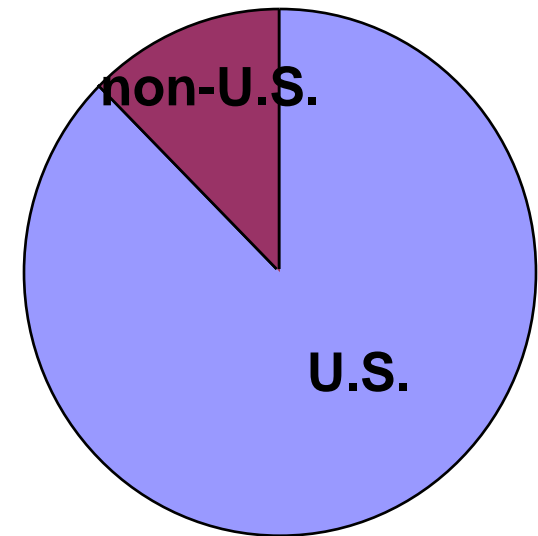
by race & ethnicity



by gender



by citizenship



Study Groups Within Cohort 1

Group	No. of subjects (per campus)	Type of data collected	
High contact	8	Ethnographic observations Semi-structured interviews	Surveys Academic Transcripts, Engineering design tasks
Medium contact	8	Semi-structured interviews Structured interviews (year 1 only)	
Low contact	24	Structured interviews	

Selected Findings: APS

- » Identity * (Semi-structured Interviews; Stevens)
- Design (Engineering Thinking and Doing; Atman)
- Institutional Factors (Structured Interviews; Fleming)
- PIE Survey (Survey; Sheppard)
- Transition to Work (Interviews; Sheppard, Stevens)

Identity*^{*}: Becoming an Engineer

Stevens, Lead; Amos, Garrison, Jocuns

- Identification
 - The practices by which an individual becomes identified with engineering (by her/himself and by others)
- Navigation
 - How individuals navigate a pathway to becoming an engineer
- Accountable Disciplinary Knowledge
 - Actions when performed are counted by someone as engineering knowledge

Identification (Changes over time)

- Increasing solidarity with other engineering students
 - We/they language, “Techies” and “Fuzzies”
 - Identity displays – websites, clothing, social activities
- Increasing expression of views that they are different from non-engineering students
 - Engineering work is harder
 - Harder work justifies future lifestyle

Navigation at UWest

Different navigational pathways have a clear effect on identification of students as engineers

- Students not admitted during their first year can be lost during this pre-engineering phase.
- Once admitted to engineering majors, students are granted literal “keys to the clubhouse” — a critical rite of passage that changes how students identify themselves as engineers.
- Students also took a more agentive stance to coursework and learning once admitted.

Gender Identity/Navigation at UWest

- Women and men both form identities as engineers that seem quite similar across the genders and draw on stereotypical engineering image (problem solver, good at math, etc.)
- However, in competitive admission practices at UWest women students are believed to have an advantage over men; presence of organizations supporting women also seen by men as evidence that women need help.
- Men use this explanation of women having an advantage in admission to set up a rationale (that involves no fault of their own) for their potential failure to get into the major.
- It is suggested that some believe that women who get into the major may be less qualified than men who do not. This leads to women working to “prove themselves” or working to appear deserving of being in engineering. This seems cultivate some *stereotype threat* (Steele).
- Women go ‘underground’—seeking help from other women as a first resort, makes them sensitive to criticism of their male peers

Accountable Disciplinary Knowledge (Changes over time)

During first two years:

- Technical subject matter prerequisites (mathematics, physics, chemistry) outside of engineering. Little exposure to engineering coursework.
- Lecture-based teaching, individual-based problem sets and exams (except labs)

During latter two years:

- Kinds of problems to be solved shifts to more open-ended problems
- Students' relationship to data changes. They go from mathematical puzzle solvers to data users to data collectors
- Biggest changes in accountable disciplinary knowledge come through in experiences of Capstone project course

Accountable Disciplinary Knowledge (Changes over time)

Examples of two UWest students handling this change over time:

- Adam struggled as problem-set based mathematics (school math) was displaced by group work and open-ended problems
- Simon came into his element with the AA capstone; he drew on his wind tunnel experience (he ran the wind tunnel at UWest) and was the expert in some of the tests (even in relation to the professors/instructors)

Identity Summary

- Complex relationships between
 - Identification
 - Navigation
 - Accountable Disciplinary Knowledge
- Pathways for individuals vary greatly

Selected Findings: APS

- Identity (Semi-structured Interviews; Stevens)
- » Design * (Engineering Thinking and Doing; Atman)
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Engineering Thinking & Doing

Atman, Lead; Kilgore, Lund, Morozov, Yasuhara

- **Thinking**

Student
conceptions of
engineering and
design,
engineering
profession

- **Doing**

Student
performance on
engineering
design tasks

ETD Selected Findings

- Year 1
 - Women more context-oriented than men *
 - Women equally capable with design details *
- » **Year 4**
 - Conceptions of engineering practice
 - Preparedness for engineering practice
- Year 1 vs. Year 4, longitudinal
 - Changes in conceptions of design

emerging findings

Preparedness for engineering practice: ABET/2020 skills/knowledge

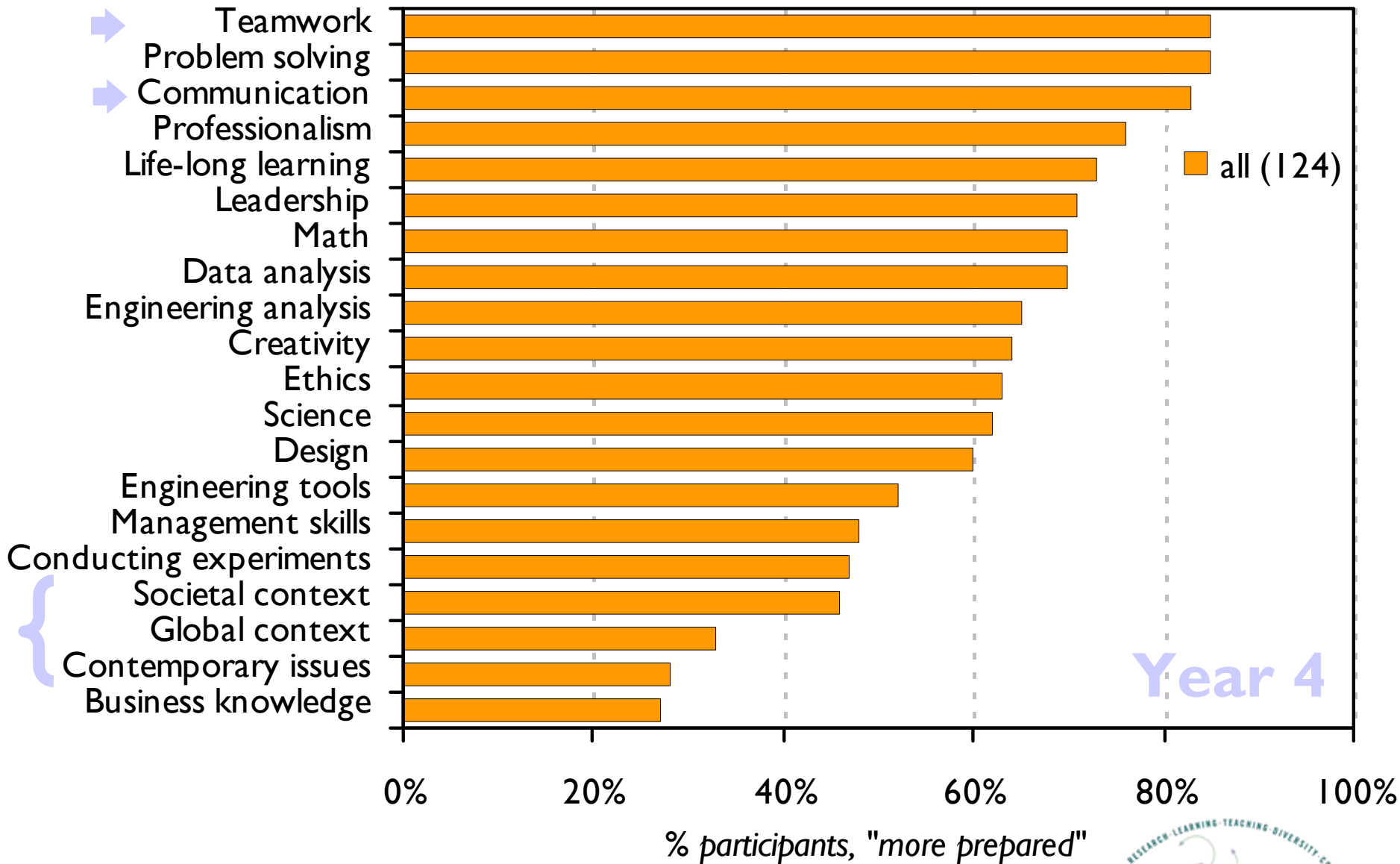
- *Please rate how well prepared you are to incorporate each of the following items while practicing as an engineer...*
- List of skill/knowledge items based on ABET a–k and *Engineer of 2020*

Not at all prepared	...	Somewhat prepared	...	Very well prepared
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less prepared

more prepared

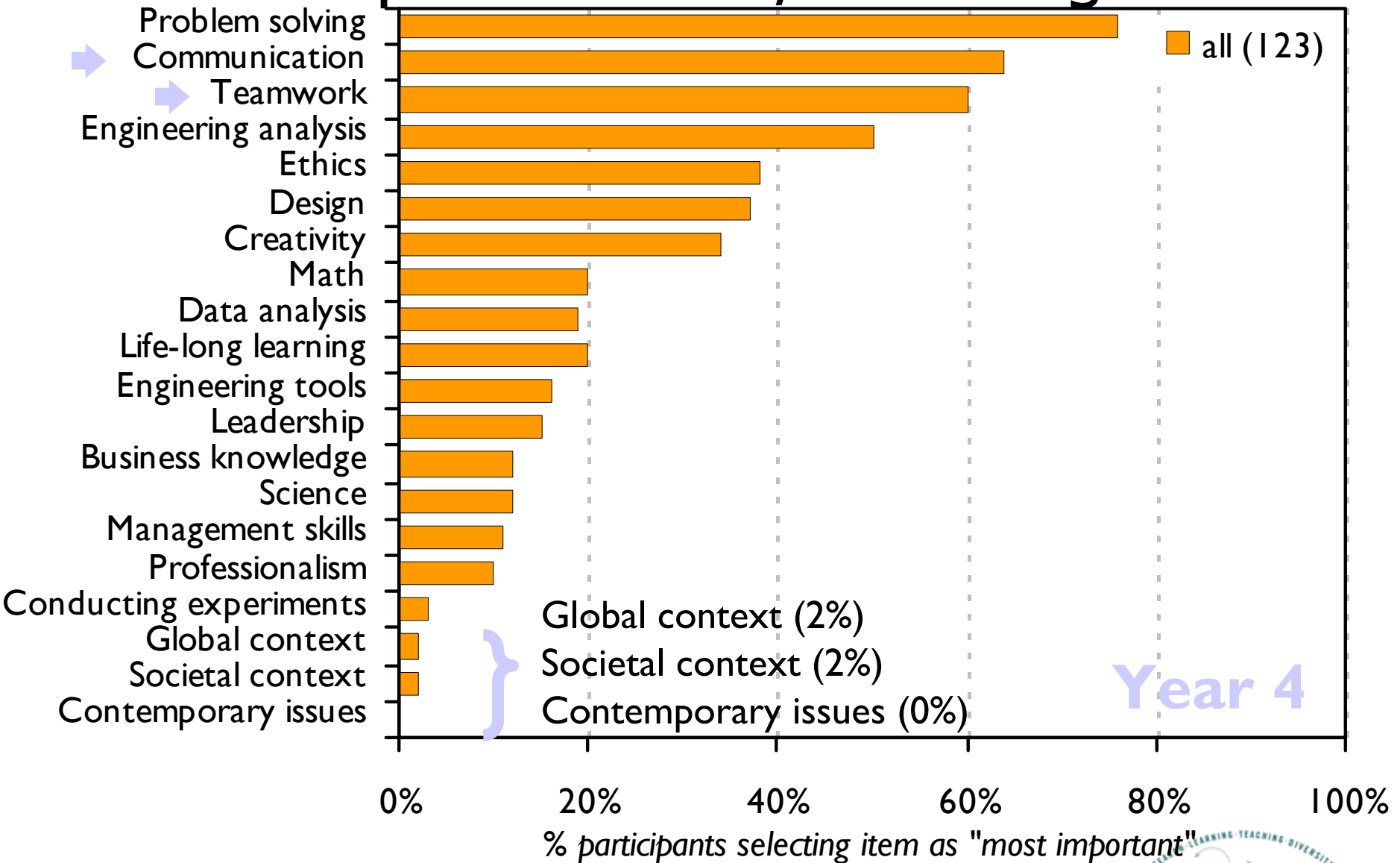
Skills/knowledge preparedness



Conceptions of engineering practice: ABET/2020 skills/knowledge

- *Of the 20 items below, please put a check mark next to the FIVE you think are MOST IMPORTANT to practicing engineers...*
- Same list of ABET/2020 skill/knowledge items

Important skills/knowledge



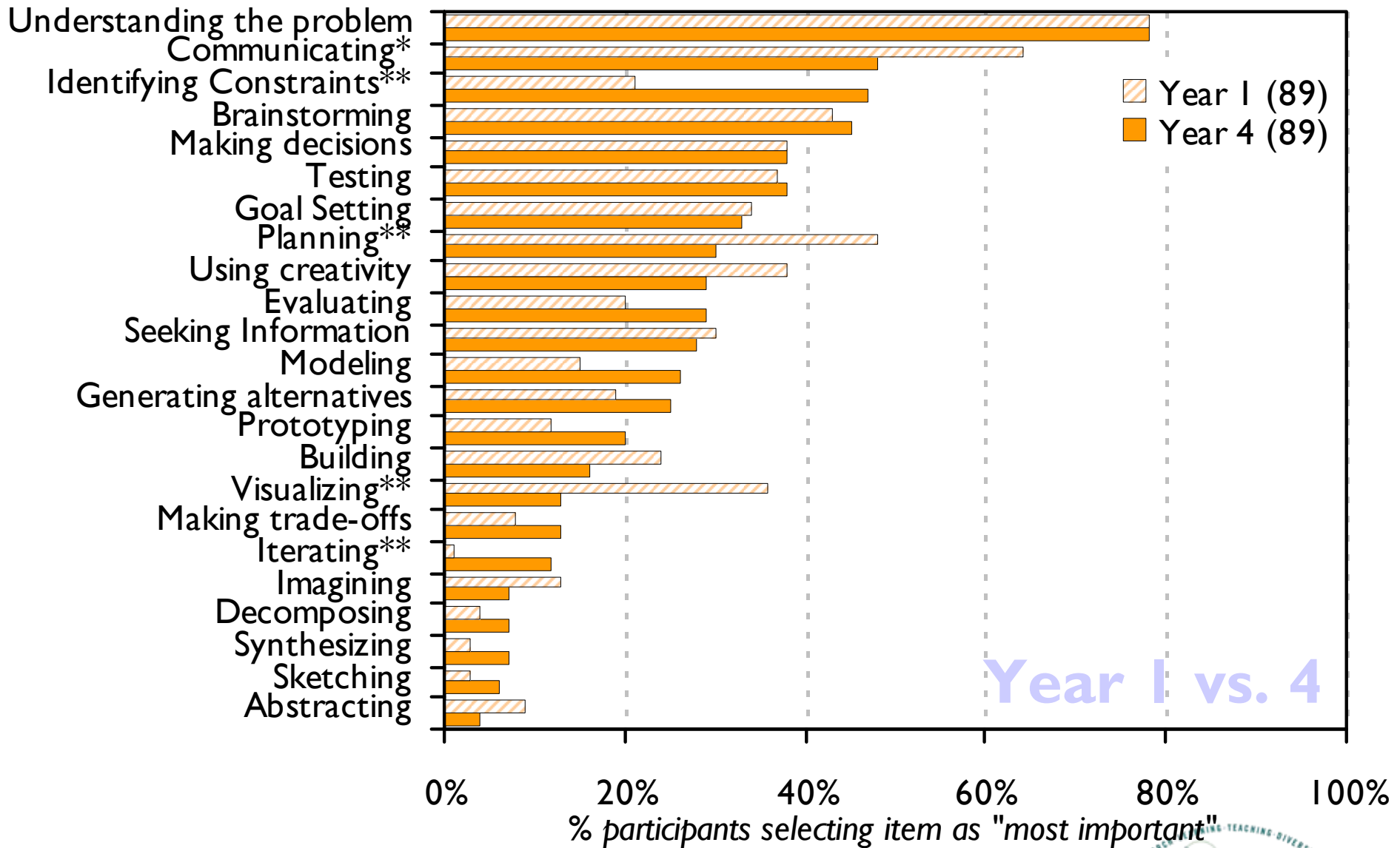
ETD Selected findings

- Year 1
 - Women more context-oriented than men *
 - Women equally capable with design details *
- Year 4
 - Low importance, preparation for contextual issues *
 - High importance, preparation for “people” skills
- » **Year 1 vs. Year 4, longitudinal**
 - Changes in conceptions of design

Conceptions of design: Important design activities

- *Of the twenty-three design activities below, please put a check mark next to the SIX MOST IMPORTANT...*

Important design activities, by year



Significant changes asterisked (** $p \leq 0.01$, * $p \leq 0.05$).

Important design activities, changes

**down in
Year 4**

Communicating*
Planning**
Using creativity
Building
Visualizing**
Imagining
Abstracting

**up in
Year 4**

Identifying constraints**
Evaluating
Modeling
Generating alternatives
Prototyping
Making trade-offs
Iterating**
Decomposing
Synthesizing
Sketching

Significant Year 1–4 changes asterisked (** $p \leq 0.01$, * $p \leq 0.05$).

ETD Summary

- Complex gender differences
 - First-year women more context-oriented, but not at the expense of focus on design details.
 - Implications on continuing challenge to recruit, retain women.
- Meeting the ABET a–k and *2020* challenges
 - Seniors value and have learned traditional “core” engineering, as well as some “people” skills (teamwork, communication).
 - ...but not issues of societal/global context, contemporary issues.

ETD Summary, cont.

- Maturing conceptions of engineering design
 - More precise, engineering-specific vocabulary
 - More similar to expert conceptions
 - Reflections of local curricular emphases?

Selected Findings: APS

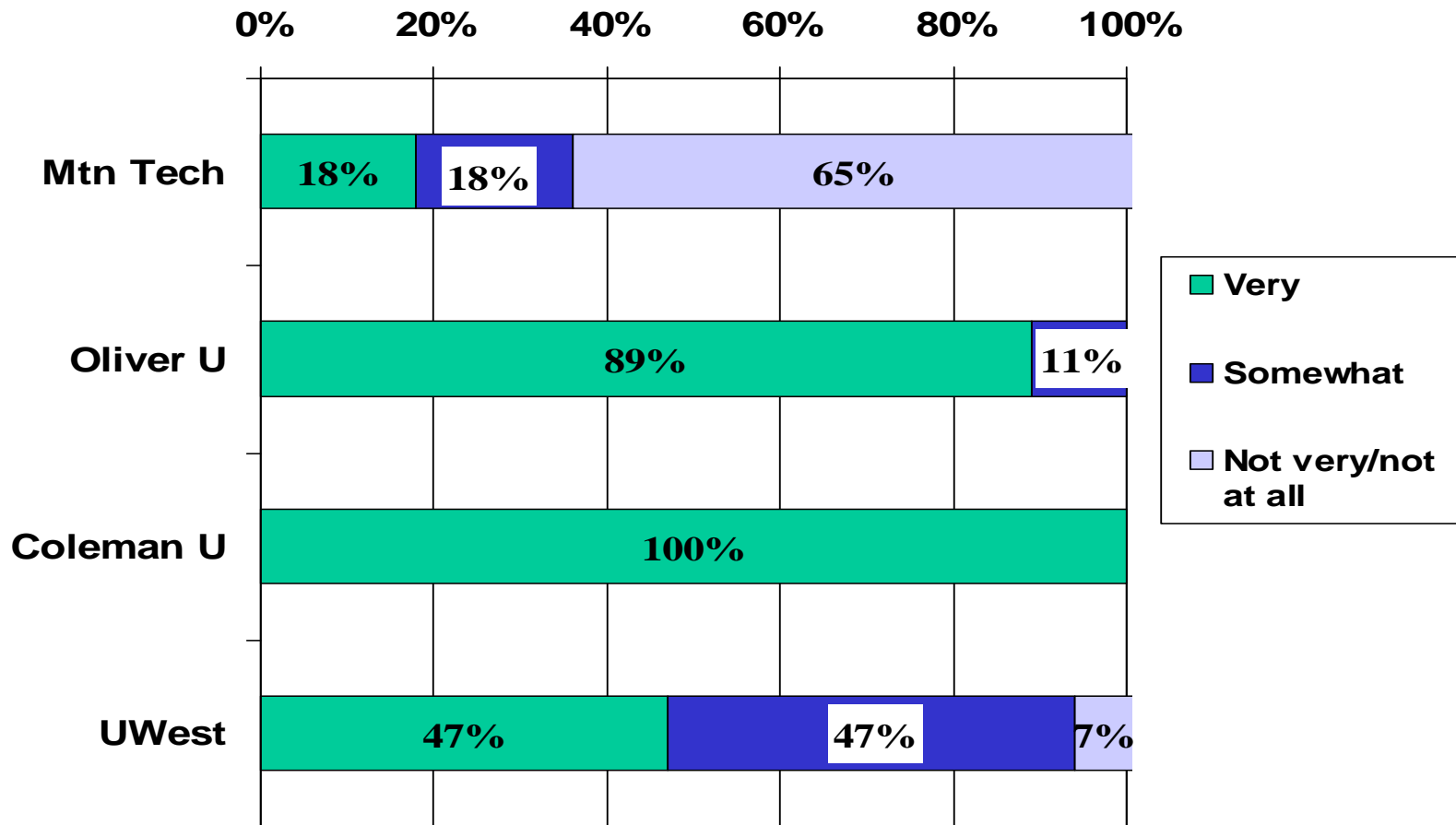
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- PIE Survey (Survey; Sheppard)
- Transition to Work (Interviews; Sheppard, Stevens)

Institutional Factors

Fleming, Lead; Ledbetter, McCain, Williams

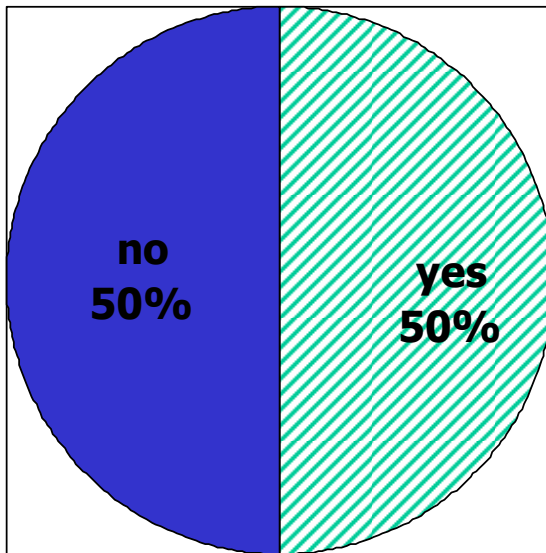
- Admission Policy
- Access to Resources
- Experiences Within University Environment
- Diversity Issues

To What Extent Do You Consider Your School to be Diverse?

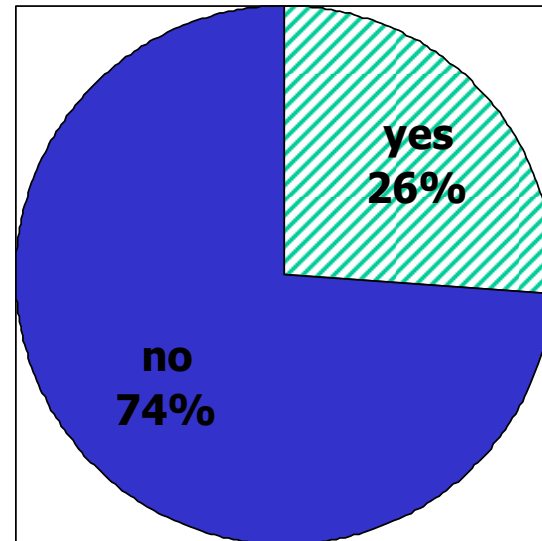


Does Your Gender Affect Your Views of Becoming an Engineer?

Females



Males



Female Student's View

Does your **gender** affect your views of becoming an engineer?

"... there are societies, like Society for Women Engineers...that does help change our perspective on being an engineer
...it's 'cause I'm female, because I'm a minority and I'm not used to being like that because I'm a white middle class individual
... it's hard to become an engineer, it's real intimidating to be ahm, working for... predominantly all males...it's kind of a challenge to me,
...I can do this, I can pioneer this and be a female engineer, be just as good as a male engineer" *Mountain Tech*



Male Students' View

Does your **gender** affect your views of becoming an engineer?

"...if the females... have an advantage, just because [of] things like affirmative action ... where they give certain advantages to some minorities, I wonder if it is a disadvantage being the majority?" *University of West State-M*



2007 CASEE Symposium; October 9, 2007

"It's more natural for males to be engineers." Coleman University-M

What Does Diversity Mean To You?

- **Gender**
- **Majors**
- **Racial**
- **Ideologies**
- **Cultural**
- Socio-economic
- Social
- Geographical
- Political

Diversity Summary

- To most engineering students, diversity means difference (school, gender, race , geographical, major field, politics, religion).
- Diversity can be an uncomfortable topic for students to discuss.
- Students recognize the impact of diversity on their careers.

Selected Findings: APS

- Identity (Semi-structured Interviews; Stevens)
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- » PIE Survey * (Survey; Sheppard)
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Overview of the Survey Instruments

- **Cohort 1 ***: Persistence in Engineering Survey (PIE Survey)
- **Cohort 3 ***: Academic Pathways of People Learning Engineering Survey 1 (APPLES1)
- **Cohort 4**: Academic Pathways of People Learning Engineering Survey 2 (APPLES2)
- **Cohort 1' ***: Persistence in Engineering Survey (PIE Survey) to cross-sectional samples

PIE Survey Focus

Eris, Sheppard, Chachra, Chen, Toye

- To identify correlates of persistence in engineering *
- **ACADEMIC PERSISTENCE** is operationalized as majoring in engineering
- **PROFESSIONAL PERSISTENCE** is operationalized as expressing an intention to practice engineering for at least 3 years after graduating with a bachelor's degree.

PIE Constructs

- 1a. Academic persistence
- 1b. Professional persistence
- 2a. Motivation (financial)
- 2b. Motivation (family influence)
- 2c. Motivation (social good)
- 2d. Motivation (high school teacher/mentor influence)
- 2e. Motivation (mentor influence)
- 3a. Confidence in math and science skills
- 3b. Confidence in professional and interpersonal skills
- 3c. Confidence in solving open-ended problems
- 4a. Perceived importance of math and science skills
- 4b. Perceived importance of professional and interpersonal skills
- 5. Knowledge of the engineering profession.
- 6a. Exposure to project-based learning methods (individual projects)
- 6b. Exposure to project-based learning methods (team projects)
- 7. Collaborative work style
- 8. Extra-curricular fulfillment
- 9. Curriculum overload
- 10. Financial difficulties
- 11a. Academic disengagement (liberal arts courses)
- 11b. Academic disengagement (engineering related)
- 11c. Academic disengagement (overall)
- 12. Frequency of interaction with instructors
- 13a. Satisfaction with instructors
- 13b. Satisfaction with academic facilities
- 13c. Overall satisfaction with collegiate experience

Emerging Findings from the First Three Years

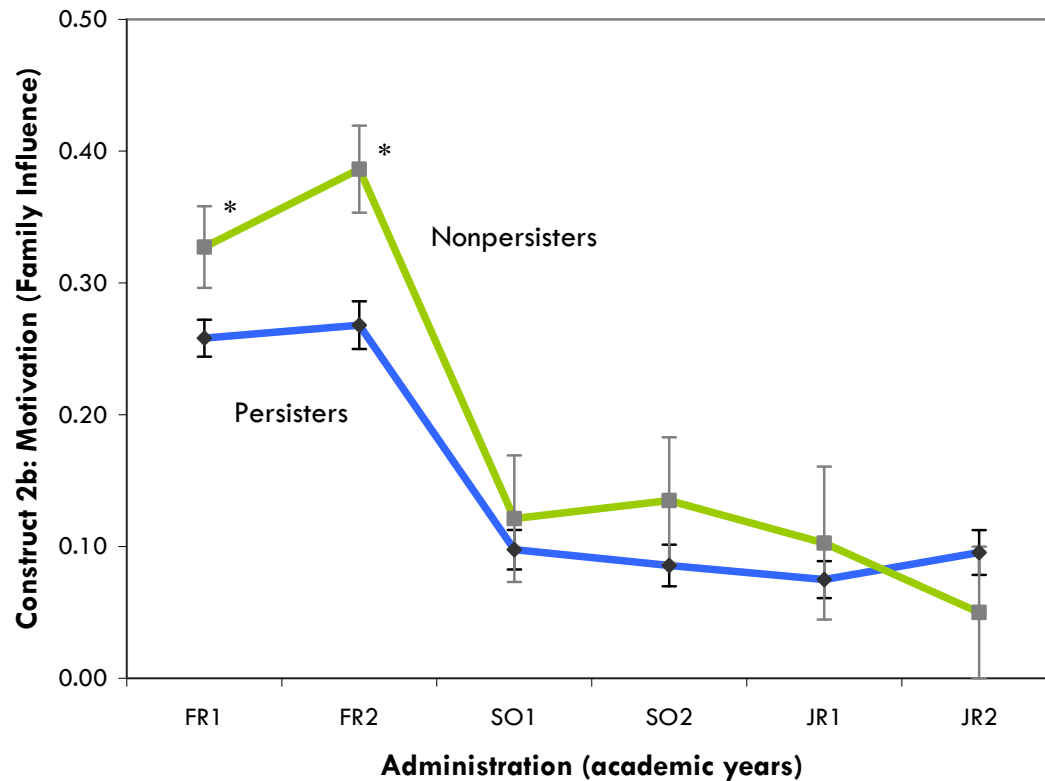
A focus on persisters/non-persisters

- motivation
- confidence
- perceived importance of skills
- disengagement/engagement

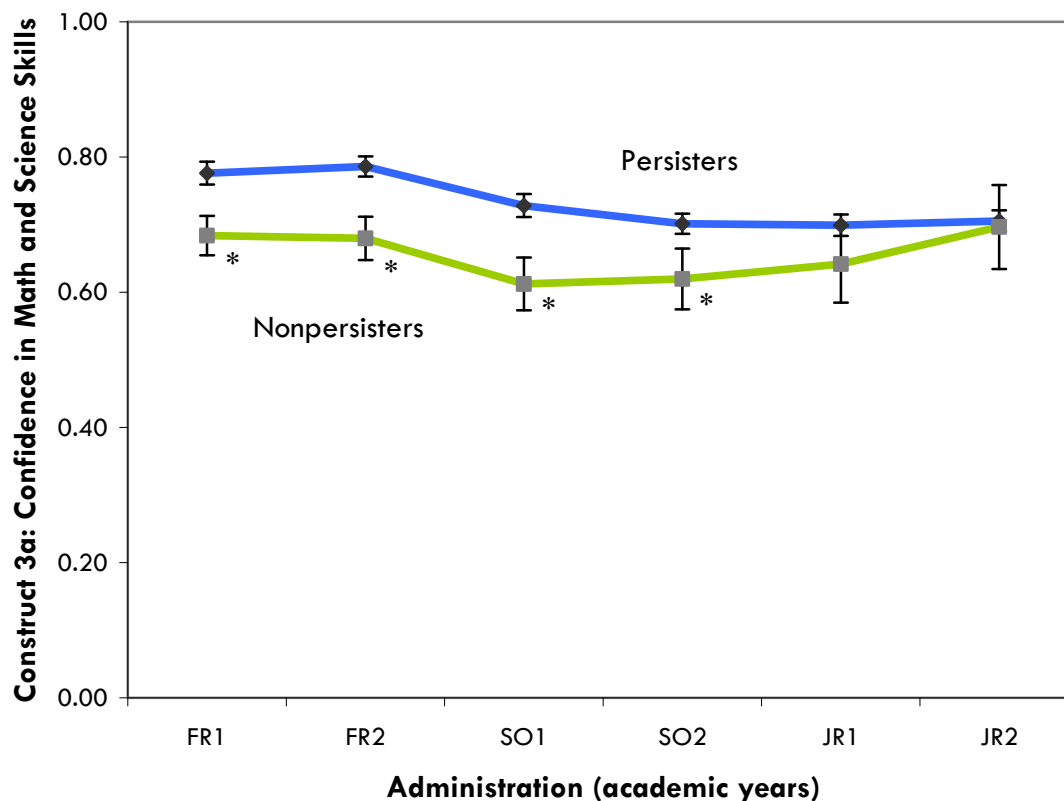
No Overall Difference Between Persisters and Non-persisters in...

- Financial motivation to pursue engineering
- Social relevance as a motivation to pursue engineering
- Perception of the importance of math and science
- Confidence in interpersonal and professional skills
- Reported familiarity with the field of engineering in first and sophomore years

Motivation: Family Influence Persisters/Non-persisters



Confidence in Math and Science Skills Persisters/Non-persisters



Persistence In Engineering Summary

Non-persisters report:

- More family influence to be an engineer at the start of their career
- Lower confidence in math and science skills
- More academically disengaged in both engineering and liberal arts courses

Selected Findings: APS

- Identity (Semi-structured Interviews; Stevens)
- Design (Engineering Thinking and Doing; Atman)
- Institutional Factors (Structured Interviews; Fleming)
- PIE Survey (Survey; Sheppard)
- » Transition to Work * (Interviews; Sheppard, Stevens)

Transition to Work: Two Threads

- Interviews with early career engineers
 - Thread 1 *
 - Interviews at large corporation and public agencies with a focus on mathematics (Stevens, Amos, Jocuns)
- Thread 2 *
- Interviews at a large corporation (Korte, Sheppard, Smith)

Emerging Findings Across the Study:

From the student perspective

Large variation in student pathways

- Reasons for choice of major
 - Financial security
 - Contribution to society
 - Influence of family or mentors
 - Good at math and science
- Curriculum and skill development issues
 - Heavy workloads, competition, stress
 - First two years give little “vision” of engineering (design and teamwork come late)
 - Understanding context vs. detail (a “systems” view)
- Perspectives on diversity
 - What it means to students’ views of becoming an engineer

Emerging Findings Across the Study: From the student perspective (cont.)

Large variation in student pathways

- **Commitment to field of engineering**
 - Affected by personal situation, learning experiences, institutional procedures
 - Decision to be an engineer re-examined often
- **Reasons for leaving**
 - Lack of confidence in math/science skills
 - Fear of losing scholarships
 - Perception that engineering is too narrow (often little understanding of the contributions of engineering to social good)
 - Factors affect men and women differently

The Stories Continue to Unfold...

- Mountains of data to be analyzed
 stay tuned
- Use of APS instruments to help tell stories at other institutions?

7th Inning Stretch

- Take me out to the...
- Turn to your neighbor and **briefly** tell them the most surprising result you've heard so far.

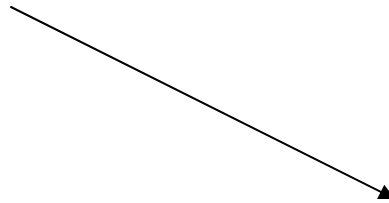
Today's Agenda

- Scholarship on Learning
 - APS
 - Scholarship on Teaching
 - SEED
- Institute for Scholarship on Engineering Education
- Summary

From Learners to Teaching

Learners

1. Identity
2. Design
3. Diversity
4. PIE Survey
5. Transition to work



Teaching

- Taken into account?
- If so, how?
- If so, are ideas in alignment..

SEED* - Studies of Engineering Educator Decisions

Turns, Lead; Huang, Sattler, Yellin

- Core Idea
 - Explore engineering teaching by focusing on teaching decisions
- Decisions as
 - Professional responsibility
 - Synthesis point
 - Reflection opportunity

Research Questions

- **What:** What types of decisions do engineering educators report?
- **How:** How did they make the decision they reported? What did they take into account? What does this reveal about their background knowledge? How do they make decisions in general?
- **A promising lens:** To what extent are they comfortable with talking about their teaching in terms of decisions?

Methods

- Interview Method
 - Anchored in Critical Decision Method
 - Two decisions – Planning then Interactive
- Participants
 - 33 participants
 - Overall
 - 14% of eligible population (n=236)
 - Gender
 - 12% of male faculty, 28% of female faculty
 - Discipline
 - 9 of 10 engineering departments
 - All academic ranks represented
 - Lecturer, Assistant, Associate, Full, Research

Reaction to Decision Lens

- Ted (SD104)
 - “That's really hard, because I don't know which type of decisions you're talking about.”
(ultimately 27 page transcript)
- Nathan (SD105)
 - “So decisions in terms of how I interact with the students or decisions in terms of how I organize my curriculum or term papers or whatever? I suppose you don't want to direct me too much because you'll just force me into giving a bad answer.” (ultimately 33 page transcript)

The Decisions

- Ted (SD104) - Planning

“...it's a lecture course only. But one of the innovations that I am trying this quarter is to take the Friday lecture and make it into a lab, so, in fact, I've reserved a lab on Fridays for a two-hour period, and our class breaks up into two groups approximately evenly. Half of them go to the lab at their normal lecture time. The other half comes an hour later.”

- Nathan (SD105) - Interactive

“And so I went back to the students, and I said, okay, he changed his date to my date. I talked to him about it, he's inflexible, so I'm changing my date, at last second...And then I said, don't tell him I did that, because he'll change his to Friday, you know...I was just pulling their leg, but, you know, the students appreciated the fact that I was willing to work with them, you know. I mean this guy...”

Time

(ASEE 2007)

- Ted (SD104)

“The class has tremendous problems because of the diversity of students coming in and the lack of sections, section meetings, and so there’s very little **time** for interaction...so the lab was in response to that.”

- Nathan (SD105)

“... I'm consistently flexible on certain things, like changing term paper deadlines and midterm dates, depending upon the needs of the audience. ...

Learners - Characteristics

- Ted (SD104)
 - “because people program at different rates”
 - “no matter how many office hours we hold, most students won’t come in, and it’s mainly because...”
 - “many students don’t want to speak up.. Because of taking up time or sticking out or whatever...”
- Nathan (SD105)
 - “during the junior year all of the students are taking the same sequence of classes...”
 - “some things are completely new to them, but I don’t know what is new to who.”

“Power”

- Ted (SD104)

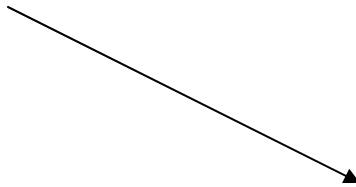
“I used to teach other classes. ... But the problem is when you're -- when **you're forced** to teach a course and you don't have any control over the format, that's a problem.”
- Nathan (SD105)

“Because **I'm trying** to network far and wide on this one so I get it off to the ground.”

From Learners to Teaching

Learners

1. Identity
2. Design
3. Diversity
4. PIE Survey
5. Transition to work



Teaching

- Taken into account?
- If so, how?
- If so, are ideas in alignment..

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- ➔ Institute for Scholarship on Engineering Education
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What Is ISEE?

Adams, Lead; Allendoerfer, Bell, Fleming, Leifer

- Build capacity: 3 Institutes (UW, Stanford, and Howard), 47 Scholars
- Develop, test, iterate on “model”
 - 3 cycles (2004, 2005, 2006)
 - Year long mentored research experience
 - Class, campus, nation “as lab”
 - Completion of last cycle – [FIE interactive session Oct 2007](#)
 - Diversity (e.g., Howard 2006 theme)
 - Rigor and impact
 - Community interactions - stories, posters, Idealog
- Conduct research: Becoming an engineering education researcher
- Scholarly contributions – Scholars and ISEE leads

Scholar Communities

- Joined an existing local group or committee
- Interact
 - with ISEE Scholars on their campus
 - with ISEE Scholars not on their campus or in their cohort
- Engage with
 - CAEE (part of team, resource)
 - Other faculty
 - College of Education and Student Services
 - broader community

What Is ISEE Impact?

- 47 Diverse Scholars (funded for 27!)
- 20 Diverse Institutions
- 30 papers, 33 presentations
 - (ASEE, FIE, AERA, NARST, etc.)



ISEE Impact Stories

- UW Scholar's ISEE project grew into an off-campus course in New Orleans, where students combined classroom learning with reconstruction assistance.
- Stanford Scholars worked with various stakeholders at Stanford to evaluate reform in engineering fundamentals courses.
- Howard Scholars will conduct an interactive workshop on a "model" for community building in engineering education at the 2007 Frontiers in Education Conference (on Saturday!).

ISEE Accomplishments

- People and community
- A model for community building
- Research findings – pathways, community, challenges
- Scholarly contributions – papers, models, impact stories
- ☑ Attend the FIE Special Session S1E, 8:00-9:30am, Saturday, October 13 for more details

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→ Summary

CAEE Accomplishments to Date

stay tuned for more ...

- Longitudinal study of the engineering learning experience *from the students' perspective*.
 - Insights into engineering teaching practices.
 - Growth of the community of engineering education research scholars.
 - Research instruments and models
 - Data-driven impact on CAEE campuses and **nationally**.
- Moving into the workshop...

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