Insights from Studies of the Undergraduate Engineering Learning Experience

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5xME Workshop

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Based upon work supported by National Science Foundation Grant No. ESI-0227558. Opinions, findings and conclusions or recommendations expressed in this material are the authors' and do not necessarily reflect the views of the NSF.

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(a peek into the student experience….)

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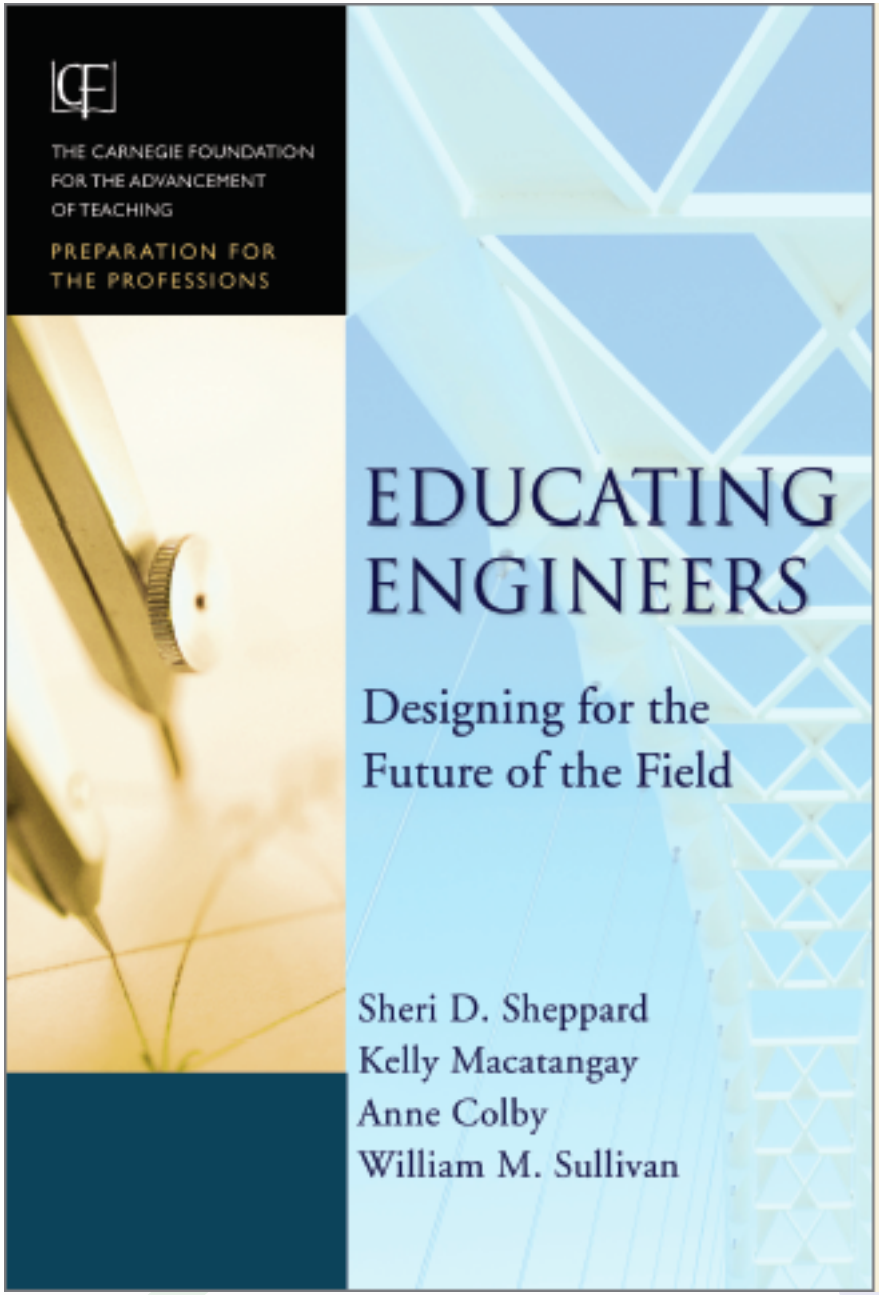
Academic Pathways Study

- **APS lead:** Sheri Sheppard
- **APS team:** Cynthia Atman, Lorraine Fleming, Ronald Miller, Karl Smith, Reed Stevens, Ruth Streveler
- **CAEE Leadership team:** Robin Adams, Cynthia Atman, Sheri Sheppard, Lorraine Fleming, Larry Leifer, Ronald Miller, Barbara Olds, Karl Smith, Reed Stevens, Ruth Streveler, Jennifer Turns

Research methods & samples

- **N NSSE national sample (2002, 2006–2007)**
  - National Survey of Student Engagement
  - *N* = 11,819; matched pairs (first-year and senior) from 247 institutions
- **L Longitudinal cohort (2003–2007)**
  - Surveys, structured interviews, ethnographic interviews and observations, engineering design tasks
  - *N* ≈ 160,* from four campuses
- **B Broad national sample (Spring 2008)**
  - APPLES2 survey
  - *N* = 4,266,* cross-sectional sample from 21 engineering colleges
- **W Workplace cohort (2007)**
  - Interviews
  - N = 17, early-career engineers at a U.S.-based, global manufacturer

*Oversampled for underrepresented groups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PREPARATION FOR
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EDUCATING
ENGINEERS
Designing for the
Future of the Field
Sheri D. Sheppard
Kelly Macatangay
Anne Colby
William M. Sullivan

Undergraduate engineering education

engineering

1 2 3 4

real life

A. Pathways in

B. Pathways through

C. Pathways out

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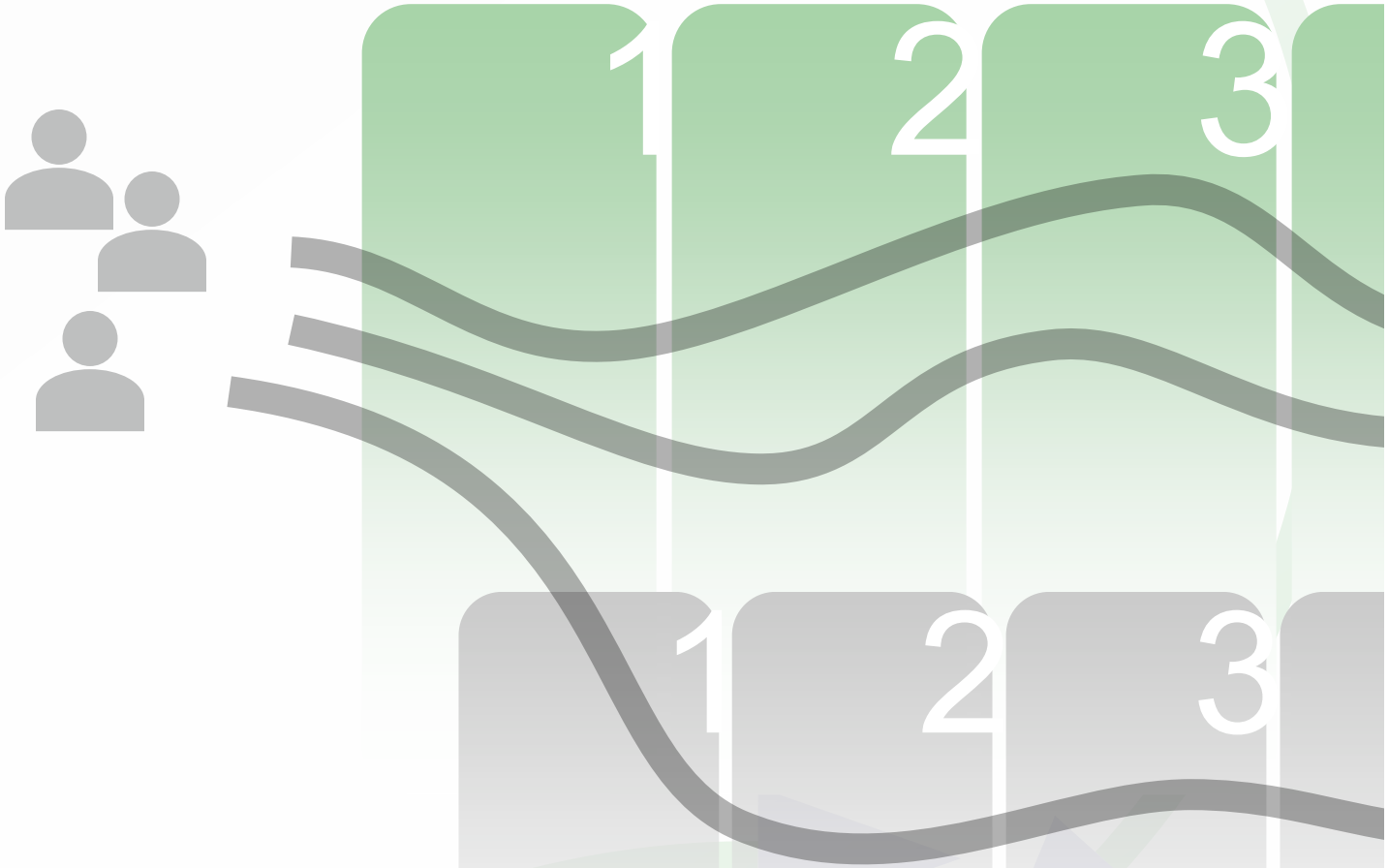
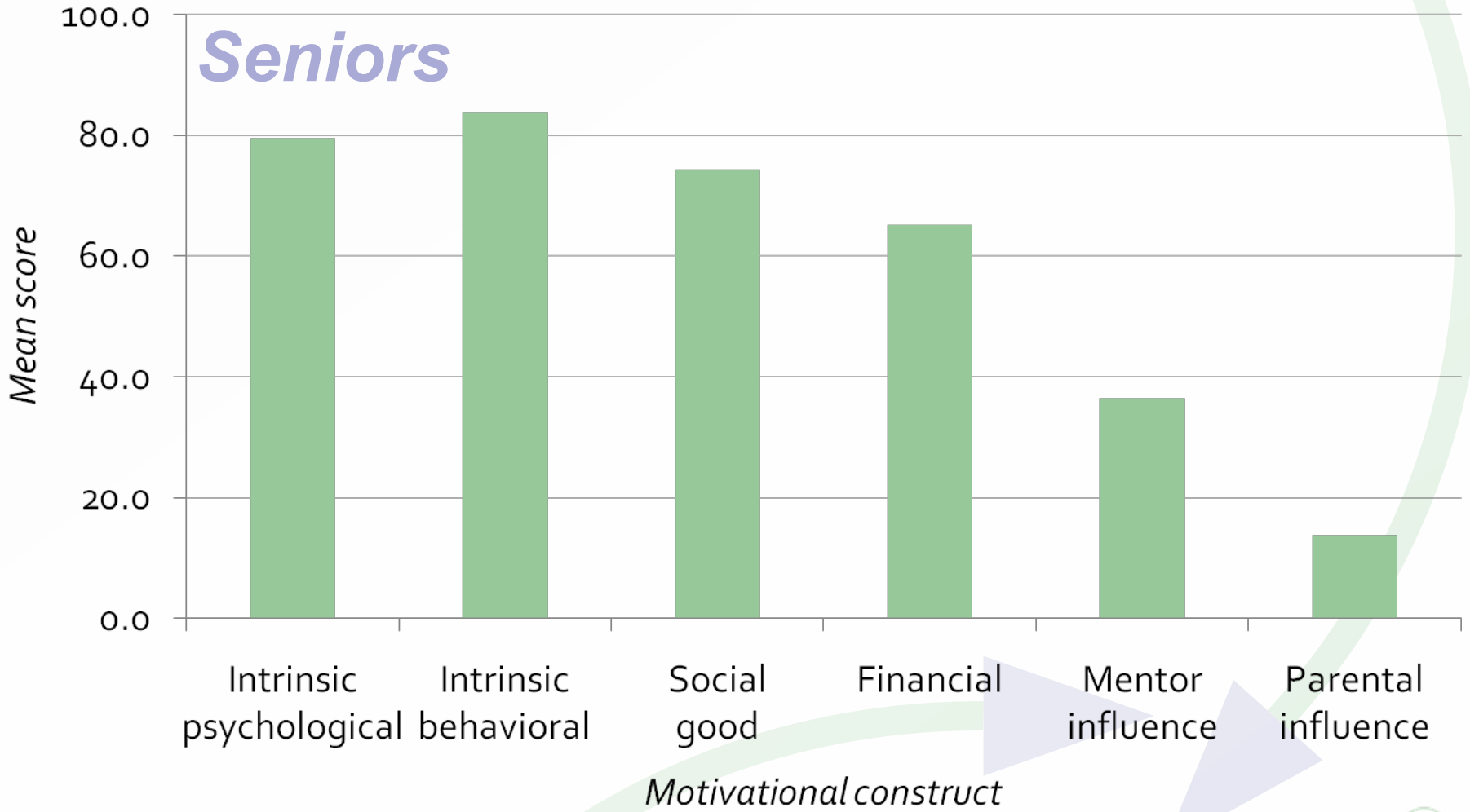
Outline

- **A. Pathways in**
  - **Student motivation**
- B. Pathways through
  - 1. What we offer
  - 2. What students learn
- C. Pathways out
  - Career choices
  - Early-career engineers

A. Pathways in

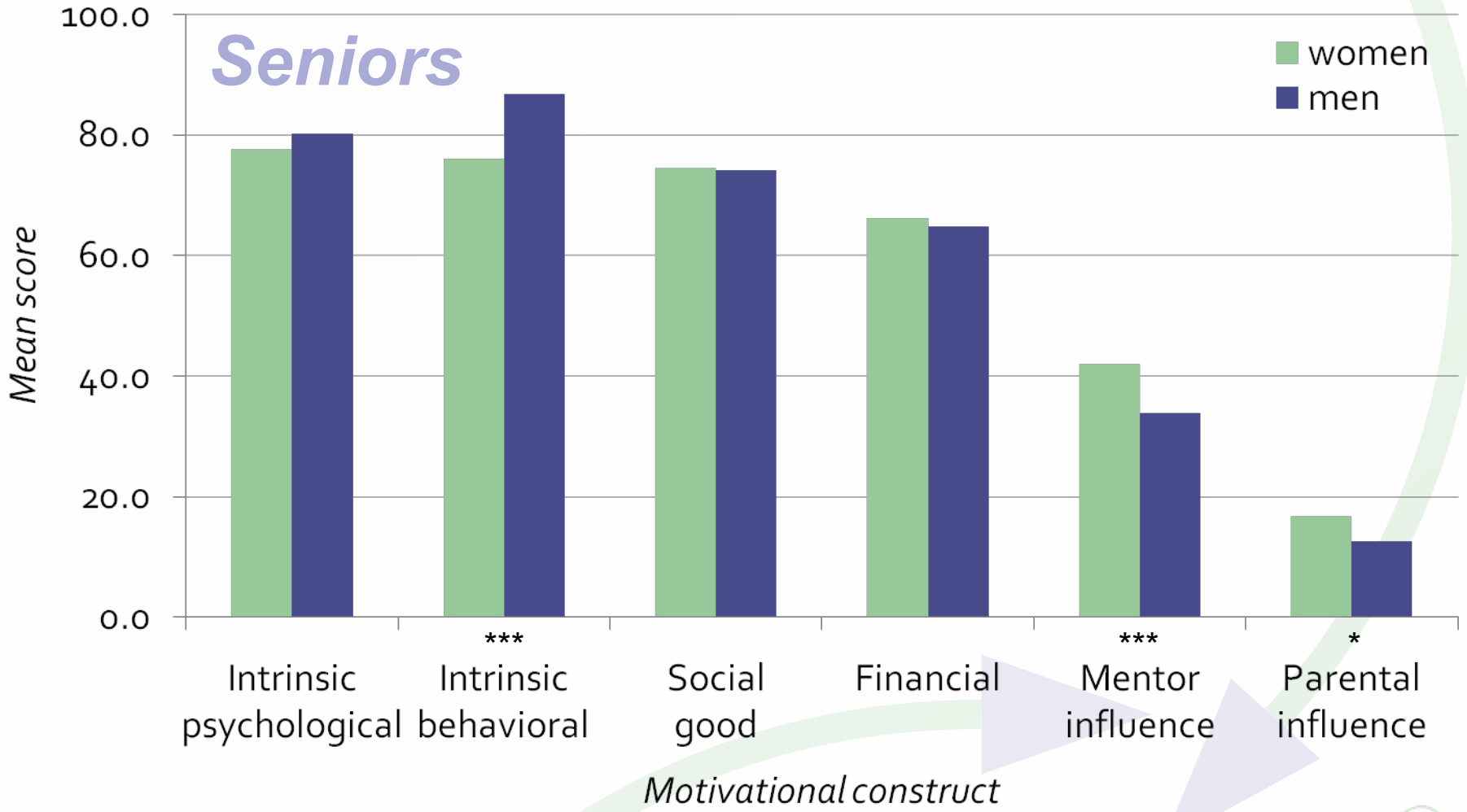


Motivation to study engineering



N = 1,130

Motivation to study engineering



*p < 0.05, ***p < 0.001; N = 326 women + 795 men

DISCUSSION:
Pathways in

Do these findings match your experiences in working with students?

How might they be better integrated into ME programs?

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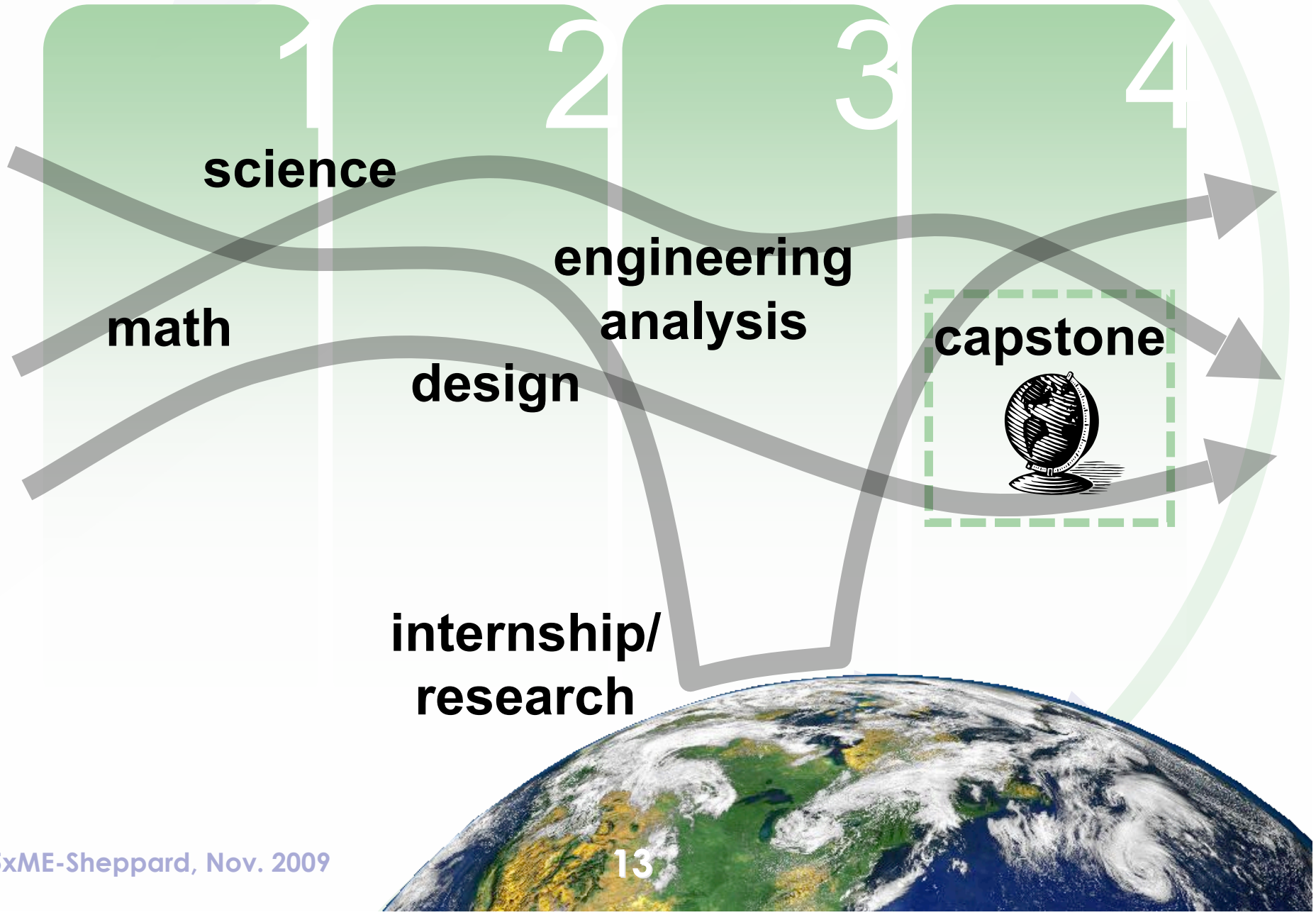
B. Pathways through



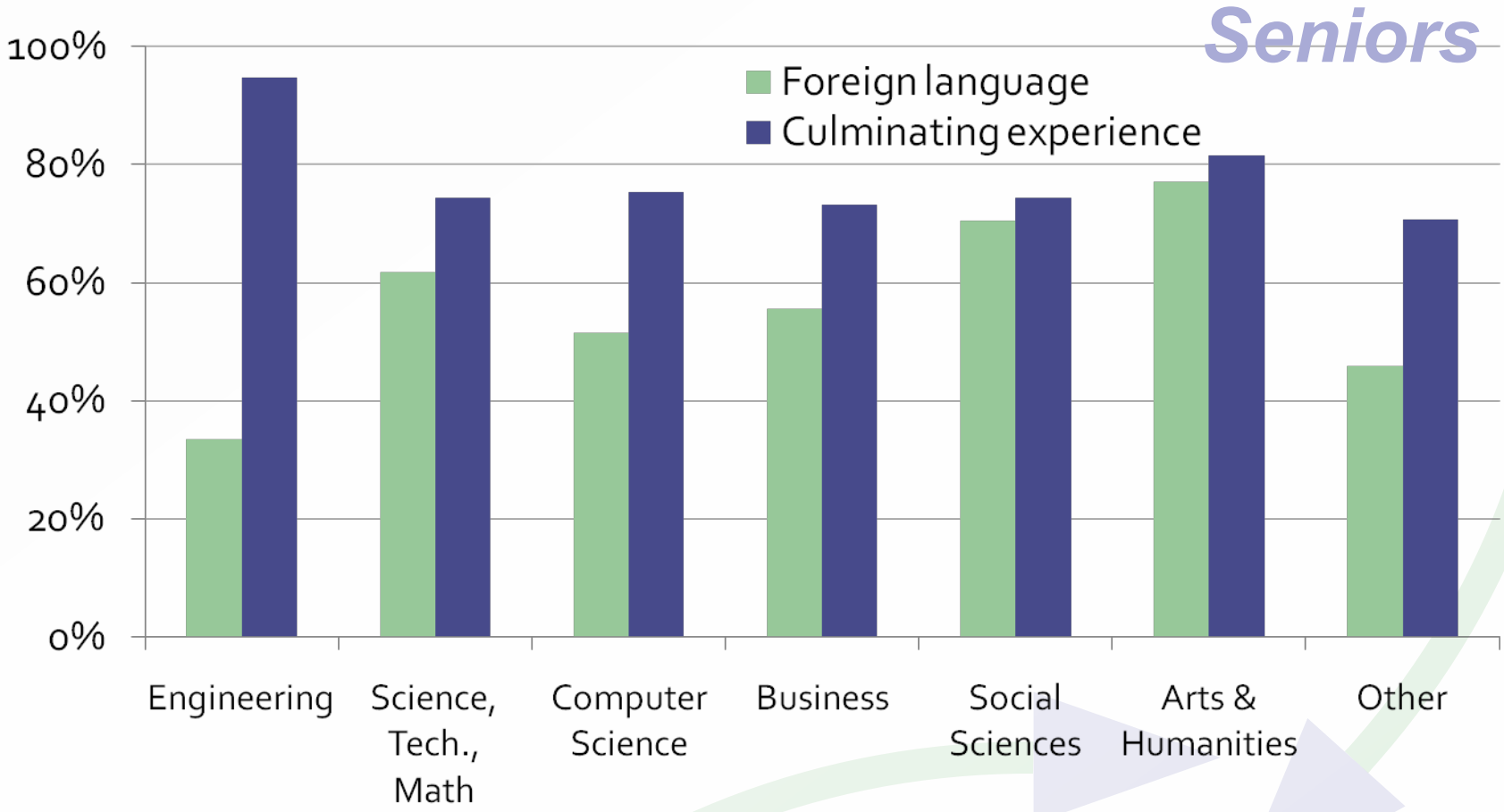
Engineering *vs.* other majors:

Educational experiences (seniors)

HIGH		LOW	
Culminating senior experience	95%	Study abroad	22 %
Practicum/co-op/ internship/field experience	86%	Indep. study/self-designed major	23 %
		Foreign language coursework	34 %

(% engineering seniors)

Engineering *vs.* other majors:
Educational experiences



Engineering *vs.* other majors:
Practices and outcomes scales

HIGH		LOW	
FY higher order thinking practices	71	Sr integrative learning practices	55
FY gains, practical competence	73	Sr reflective learning practices	54
Sr gains, practical competence	82	FY gains, gen ed	62
		Sr gains, personal & social developm't	49

(0–100 scale)

RECAP:
What we offer

- Compared with other majors, we offer more opportunities for practice, but place less emphasis on opportunities for a well-rounded education.

- What types of decisions are we forcing students to make?

Outline

- A. Pathways in
  - Student motivation
- **B. Pathways through**
  - 1. What we offer (engr. v. other majors)
  - **2. What engr. students learn, what they do**
- C. Pathways out
  - Career choices
  - Early-career engineers

Positive Change[1]: FY to Sr

scale (0-100)	FY	Sr
Engineering Research experiences (percent)	21.4	49.2
Frequency of engineering extracurricular participation	29.3	40.7
Exposure to Engineering Profession	34.7	67.7
Frequency of Interaction with Instructors	35.3	44.7
Exposure to team-based projects	54.4	64.8

1. p<.001

No Change: FY to Sr

scale (0-100)	FY	Sr
Curriculum Overload	52.0	53.6
Importance of being involved in non-engineering activities	58.3	61.0
Frequency of non-engineering extracurricular participation	71.0	73.3
Exposure to individual projects	61.2	59.2
GPA Index	70.0	68.2

Negative Change[1]: FY to Sr

scale (0-100)	FY	Sr
Pressure to Balance of Social and Academic Lives	44.8	49.4
Satisfaction with Instructors	72.4	63.9
Academic Involvement-Liberal Arts	73.3	61.2
Academic Involvement-Engineering	77.0	65.6
Overall satisfaction	78.3	71.3

1. $p<.001$

Do any of these surprise you? Are they different at your institution?

Professional/Interpersonal Skills

Professional/Interpersonal Skills:	FY to Sr Change
Confidence in…	increases! ($p<.001$)
Perceived Importance of…	slight decrease! ($p<.05$)

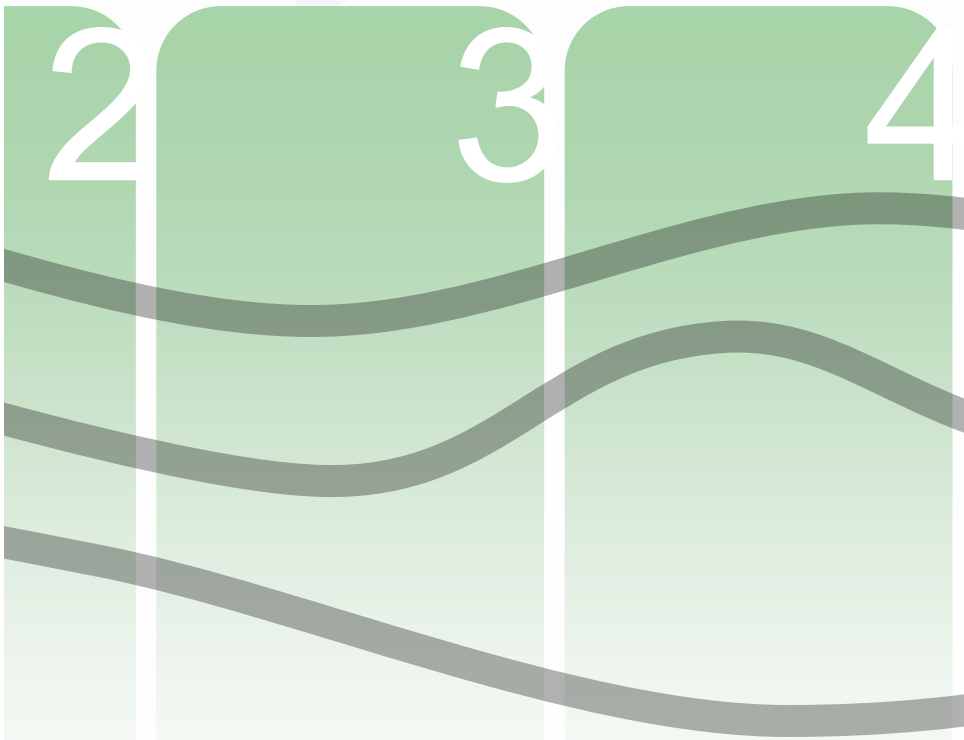
Why is perceived importance of prof/interp skills not greater among seniors?

Connecting school and work

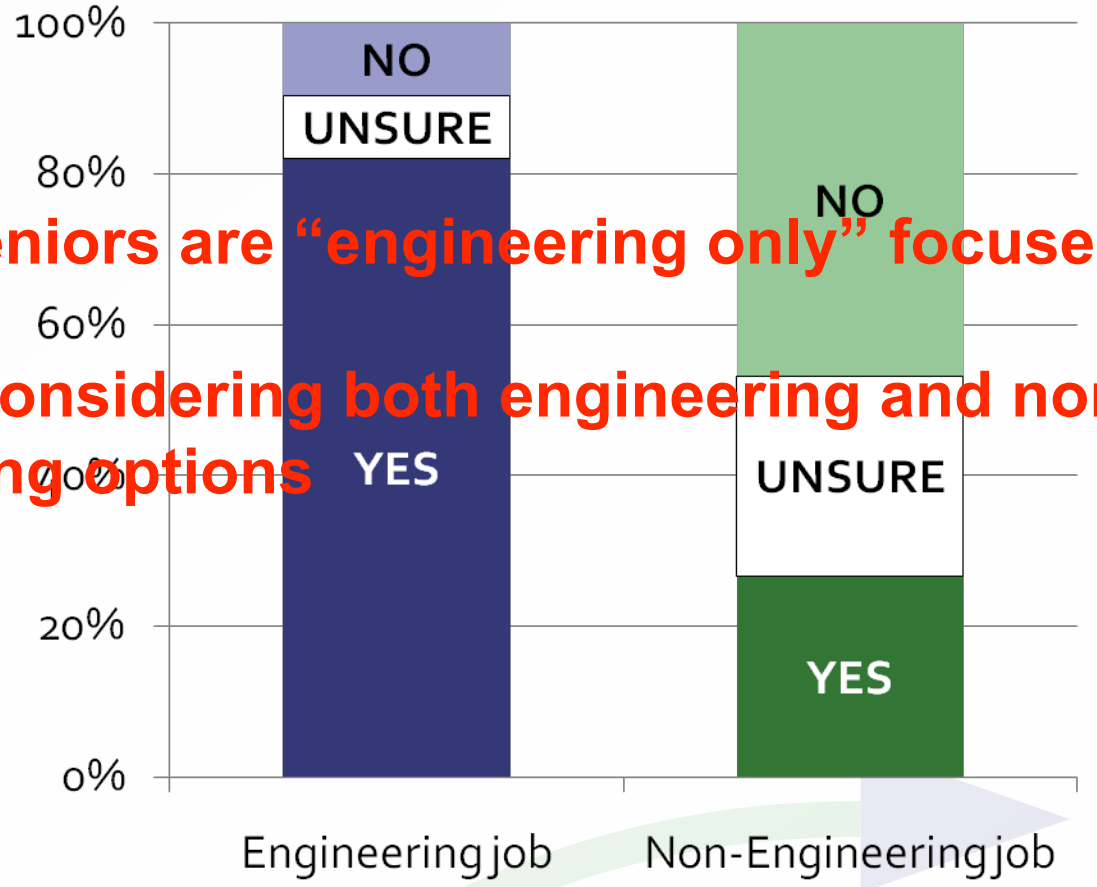
- Gaining knowledge about the engineering profession
  - from school-related experiences: Sr 60% (64% FY)
  - from work-related experiences: Sr 74% (37% FY)

Why are 40% seniors not seeing the the connection between their school experience and the engineering profession?

C. Pathways out



Post-graduation work plans



30% of Seniors are "engineering only" focused,

60% are considering both engineering and non-engineering options

Factors that predict engineering work plans

Student-level independent variables	Engr. job
1. Financial motivation	+
2. Exposure to engineering profession	+
3. Academic involvement: Engineering	+
4. Intrinsic psychological motivation	+
5. Confidence in professional and interpersonal skills	–
6. Extracurricular participation: Non-engineering activities	∅
7. GPA (self-reported)	–

positive predictor

negative predictor

Factors that predict work plans

Student-level independent variables	Engr. job	Non-Engr. job
1. Financial motivation	+	∅
2. Exposure to engineering profession	+	–
3. Academic involvement: Engineering	+	–
4. Intrinsic psychological motivation	+	–
5. Confidence in professional and interpersonal skills	–	+
6. Extracurricular participation: Non-engineering activities	∅	+
7. GPA (self-reported)	–	∅

Factors that predict engineering plans

B

42% of students

Student-level independent variables	Engr. job	Engr. grad school
1. Financial motivation	+	∅
2. Exposure to engineering profession	+	∅
3. Academic involvement: Engineering	+	∅
4. Intrinsic psychological motivation	+	+
5. Confidence in professional and interpersonal skills	−	−
6. Extracurricular participation: Non-engineering activities	∅	∅
7. GPA (self-reported)	−	+

Career choices

- Students who complete a major in engineering are not necessarily committed to careers in engineering or even STEM.
- Plans connected to motivation and confidence in skills
- Student career decisions strongly swayed by specific, significant experience, *e.g.*, internship, faculty interaction, mentor advice.

Outline

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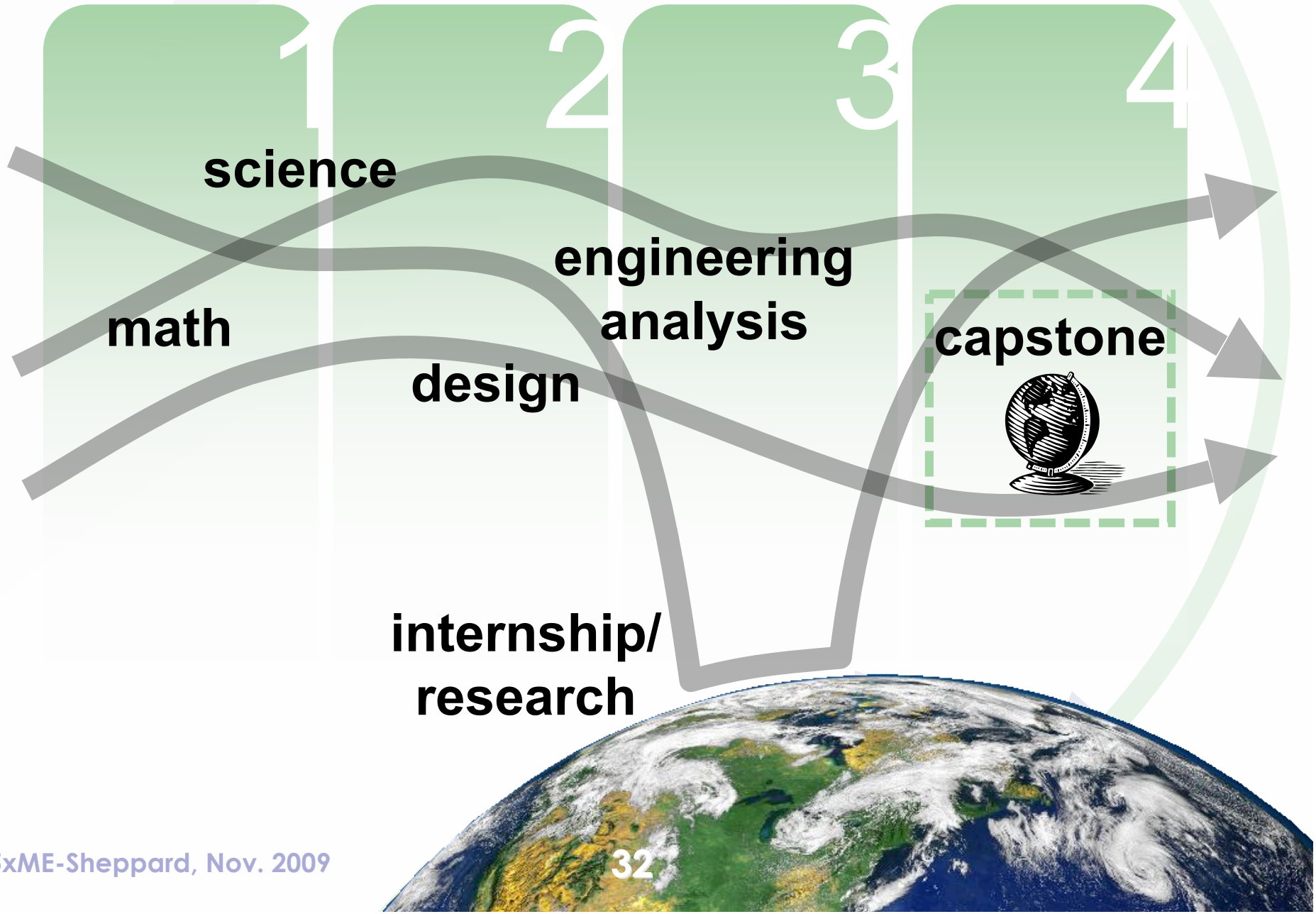
  - **Career choices**
  - **Early-career engineers**

Supporting student pathways

B. Pathways through



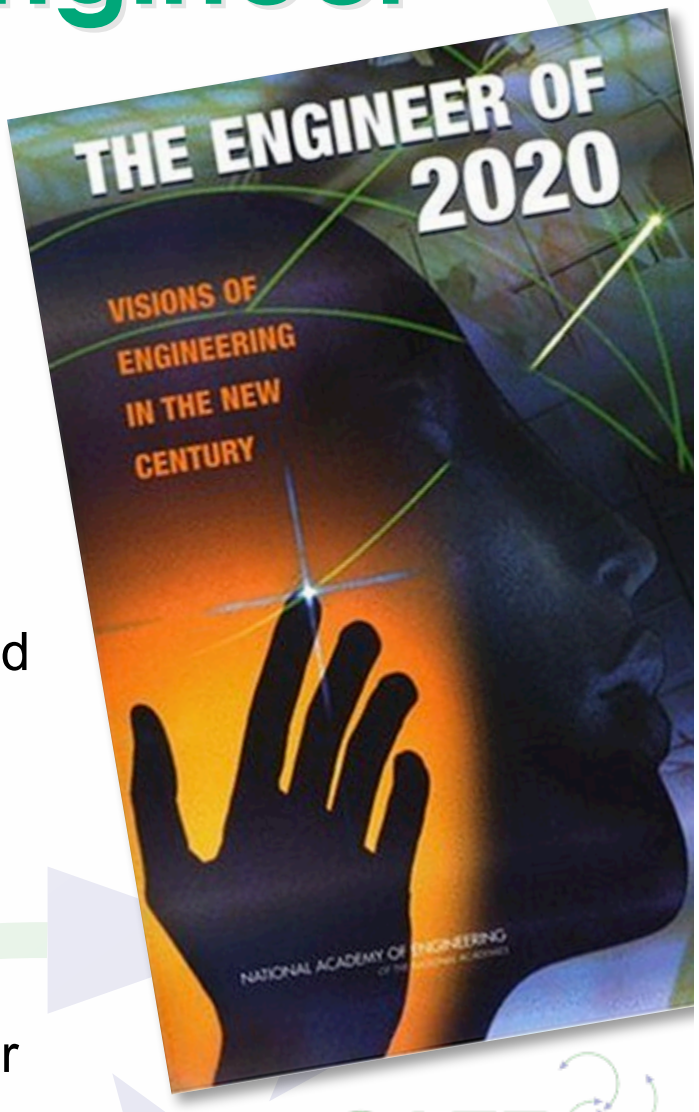
The well-rounded engineer

- Understanding engineering as discipline and profession
- Life-long learning

  "…the engineer of 2020 will learn continuously throughout his or her career, not just about engineering but also about history, politics, business, and so forth."

- Consideration of broader context

  "Successful engineers in 2020 will, as they always have, recognize the broader contexts that are intertwined in technology and its application in society."



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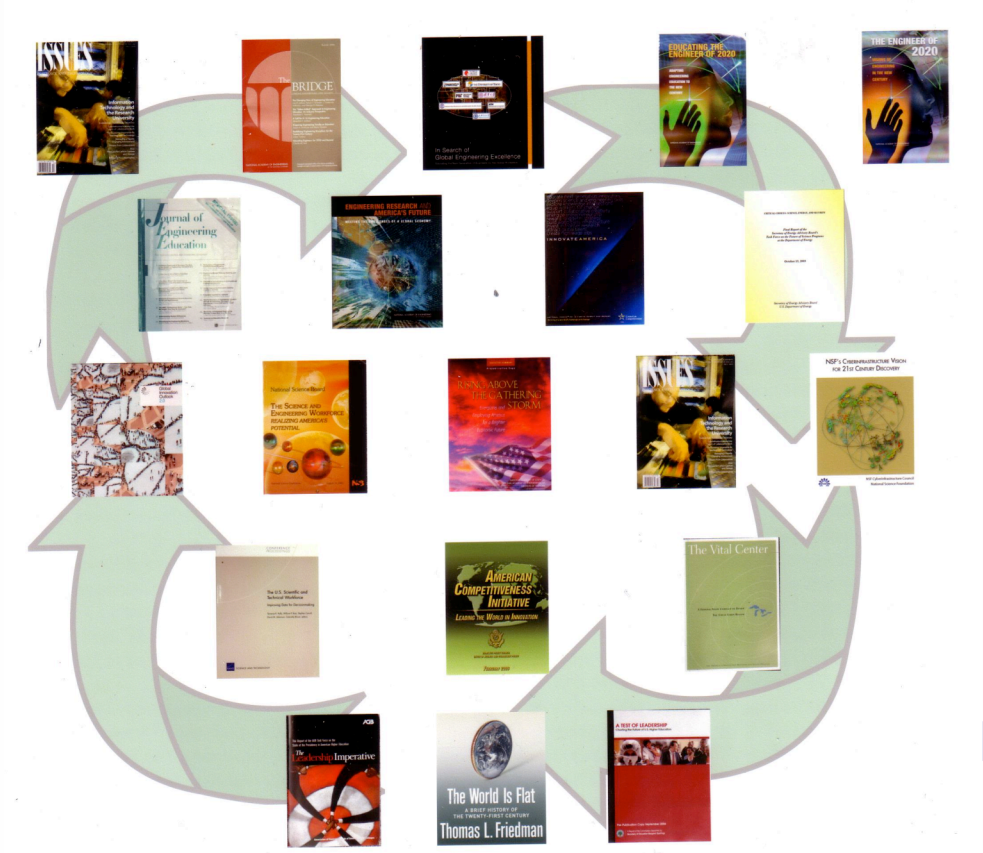
Engineering for a Changing World

A Roadmap to the Future of Engineering Practice, Research and Education

by James Duderstadt



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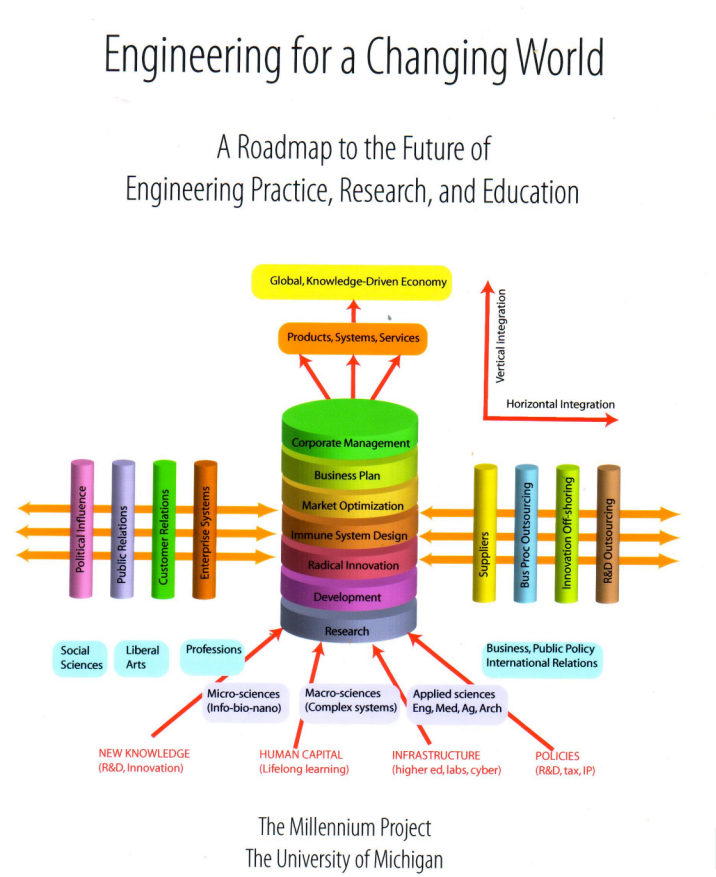

"undergraduate engineering should be reconfigured as an academic discipline similar to other liberal arts disciplines in the sciences, arts and humanities…higher education should establish graduate professional schools of engineering" (pg. iii)

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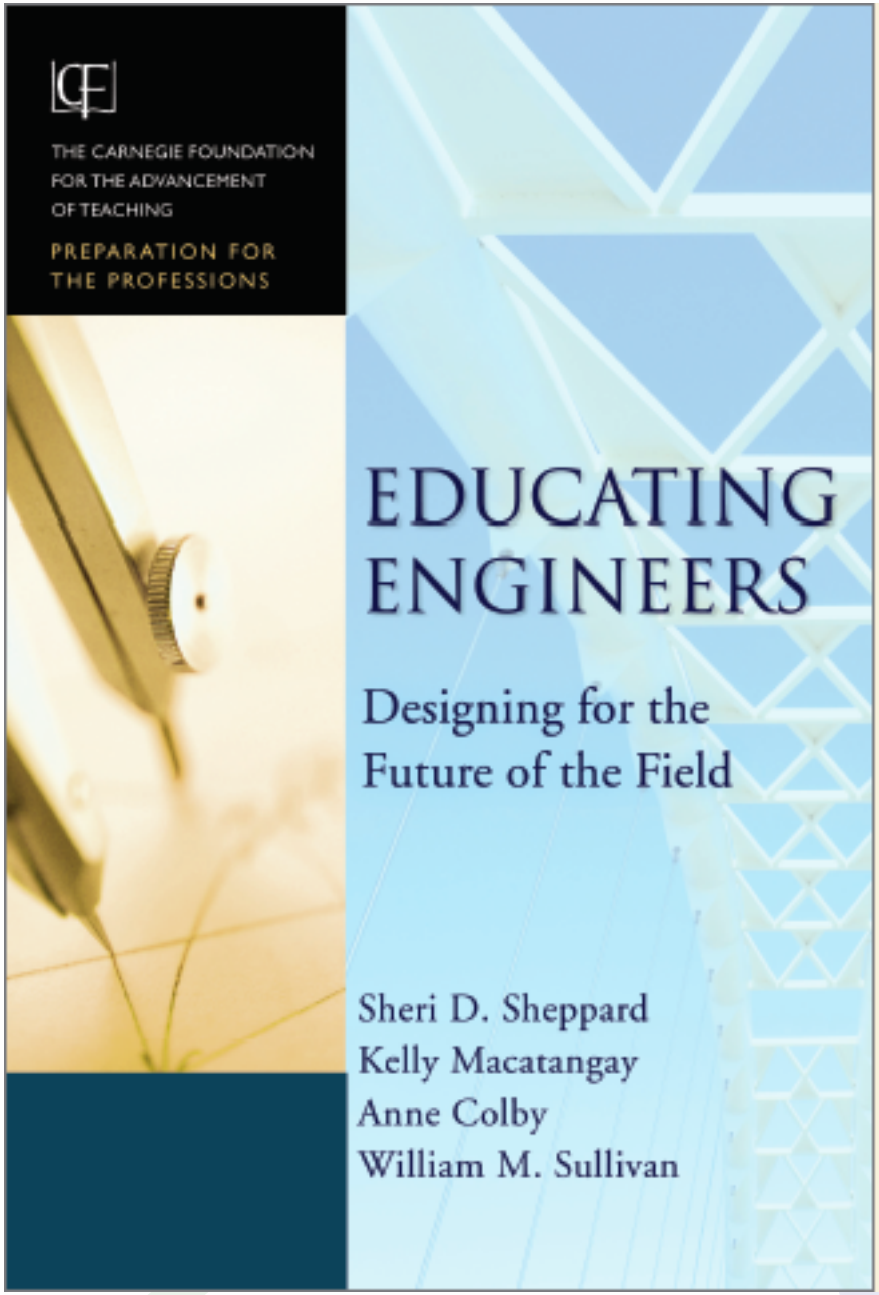
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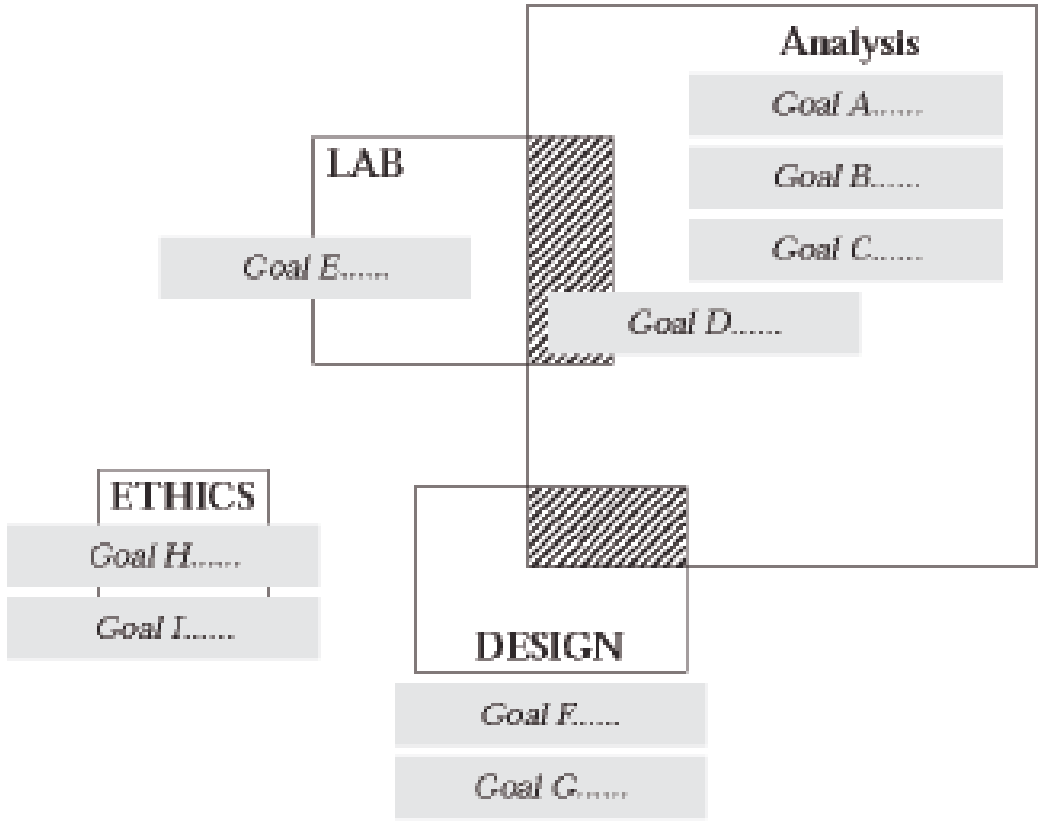
Figure 1. Linear Components Model



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Aligning Engineering Education with Engineering Practice:

1) Engineering work is inherently interactive and complex

2) Formulating problems and solving problems are interdependent activities

3) Engineering has many publics

4) Engineering incorporates many domains beyond the technical

5) Engineers affect the world

Inspiration from…

- Medical Education…
  -- circular, interpretive procedure
  -- into the guild of practitioners
- The Learning Sciences…
  -- Cognitive Apprenticeship
  -- Modeling, Scaffolding, Coaching, Fading

Educating Engineers: Designing for the Future of the Field

Table of Contents

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Professional Formation… Design Principles

1. Provide a professional spine
2. Teach key concepts for use and connection
3. Integrate Identity, Knowledge, and Skills Through Approximations of Practice
4. Place engineering in the world: encourage students to draw connections

Professional Spine

Overarching goal:
Position students for a lifetime of continuous learning and growth…

competent, responsible, fair, and accountable

Professional Spine

From the overarching goal:

- substantive knowledge of engineering science
- skills for using knowledge to interactively…
- attitudes to formulate and solve problems
- skills for effective leadership, teamwork…

Figure 1. Linear Components Model

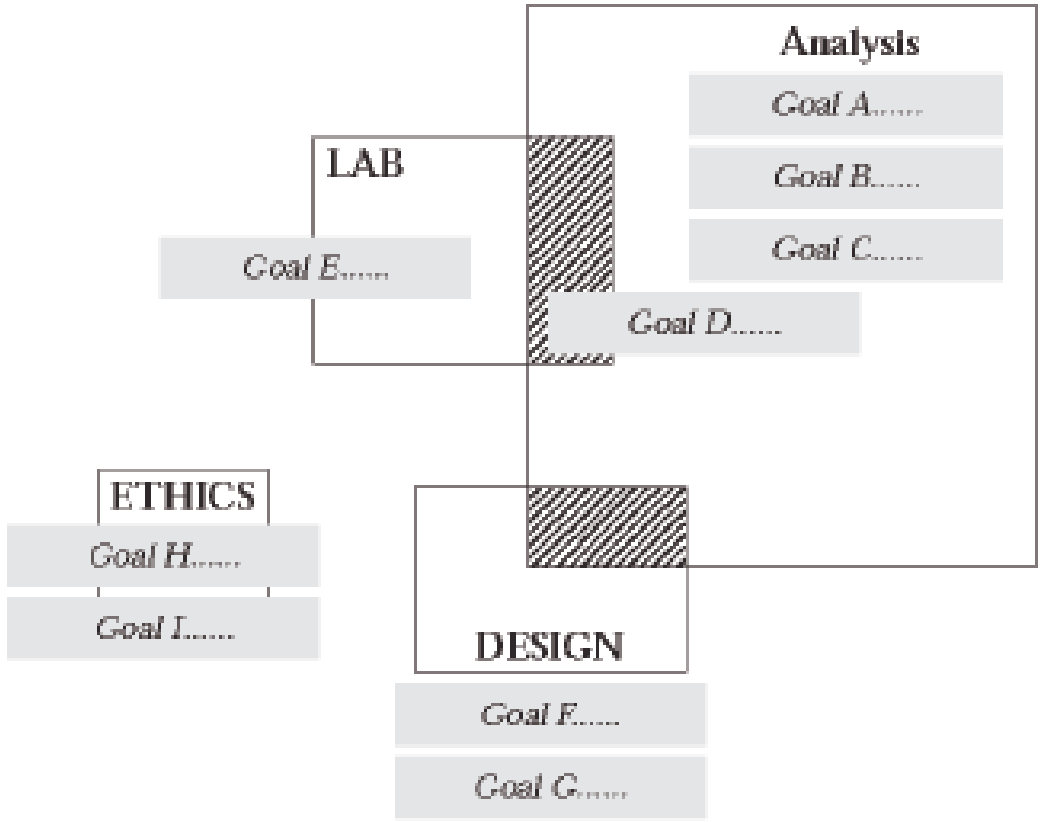

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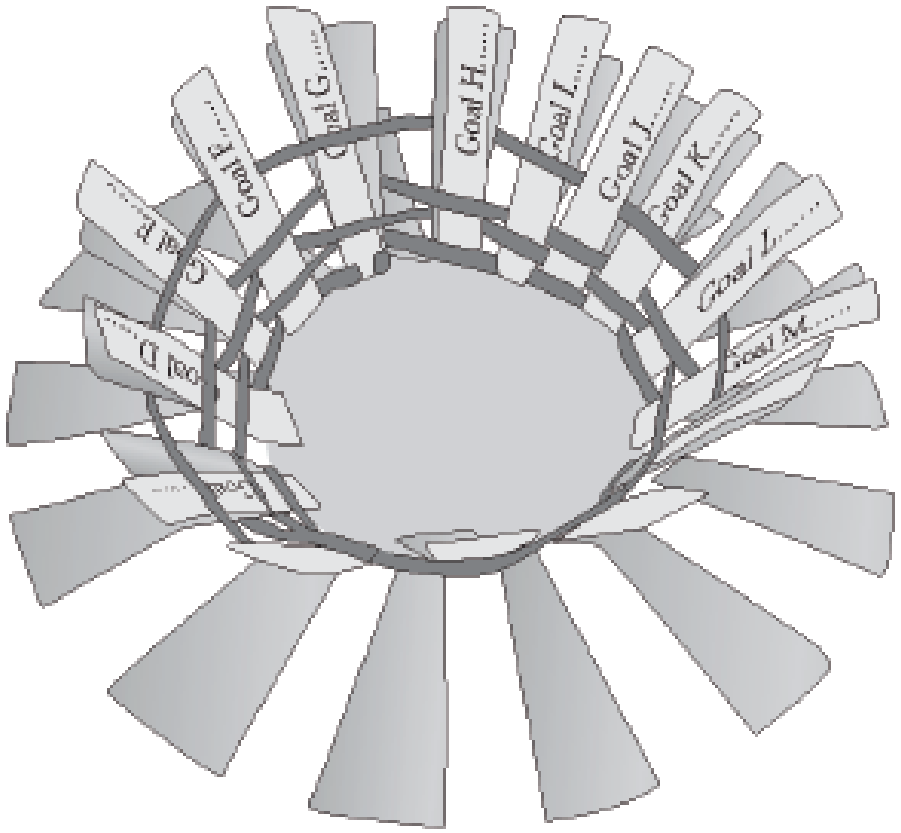
Figure 2. Networked Components Model



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DISCUSSION

1) Tapping into their motivation

2) Having a broader range of goals

3) Using a greater variety of teaching strategies

4) Connecting school to engineering work

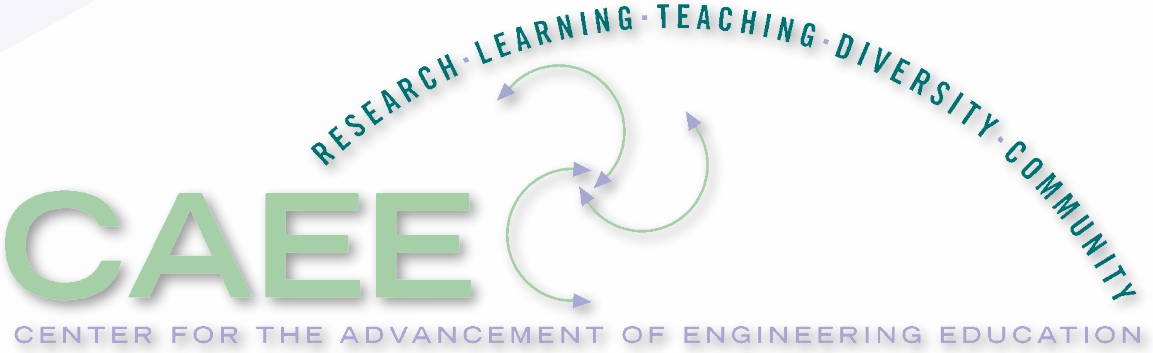
DISCUSSION

5) Building Confidence

6) Seeing themselves as professional engineers

Variety of components…

Connecting the components



http://www.engr.washington.edu/caee/

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References

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- Sheppard, S. D., Gilmartin S., *et al.* (2009). CAEE TR-09-02, Exploring the engineering student experience: Findings from the Academic Pathways of People Learning Engineering Survey (APPLES).

- Sheppard, S.D., Macatangay, K., Colby, A., Sullivan, W., *Educating Engineers: Designing for the Future of the Field,* Jossey-Bass, December, 2008.

Also check out:

more Academic Pathways Publications

http://www.engr.washington.edu/caee/publications.html

more on *Educating Engineers* (including the Executive Summary)

http://www.carnegiefoundation.org/programs/index.asp?key=30