Preparing the Engineers of 2020

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PENNSTATE
CENTER FOR THE STUDY OF HIGHER EDUCATION

Session Outline

- Introduction to the P360 study
- Connections to P2P Study
- Findings: Educational processes related to:
  - Interdisciplinary competence
  - Contextual competence
- Challenges in educating the engineers of 2020

Prototyping the Engineer of 2020:
A 360-degree Study of Effective Education (P360)

Overarching Goals:

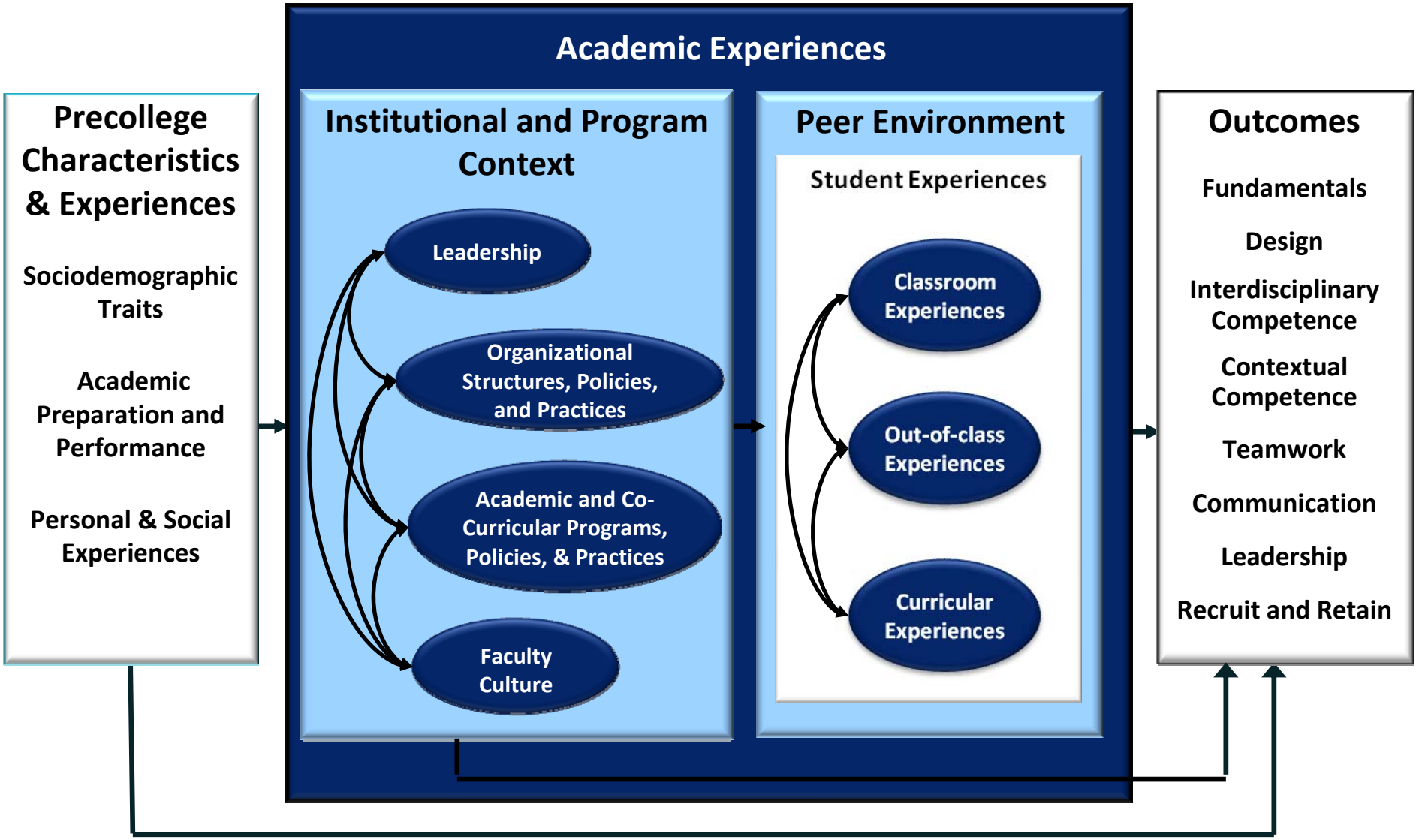
- Identify:
  - curricular, instructional, cultural, and organizational factors that produce graduates with the attributes of the engineer of 2020
  - factors supporting recruitment and retention of women and historically underrepresented students

Strategy:

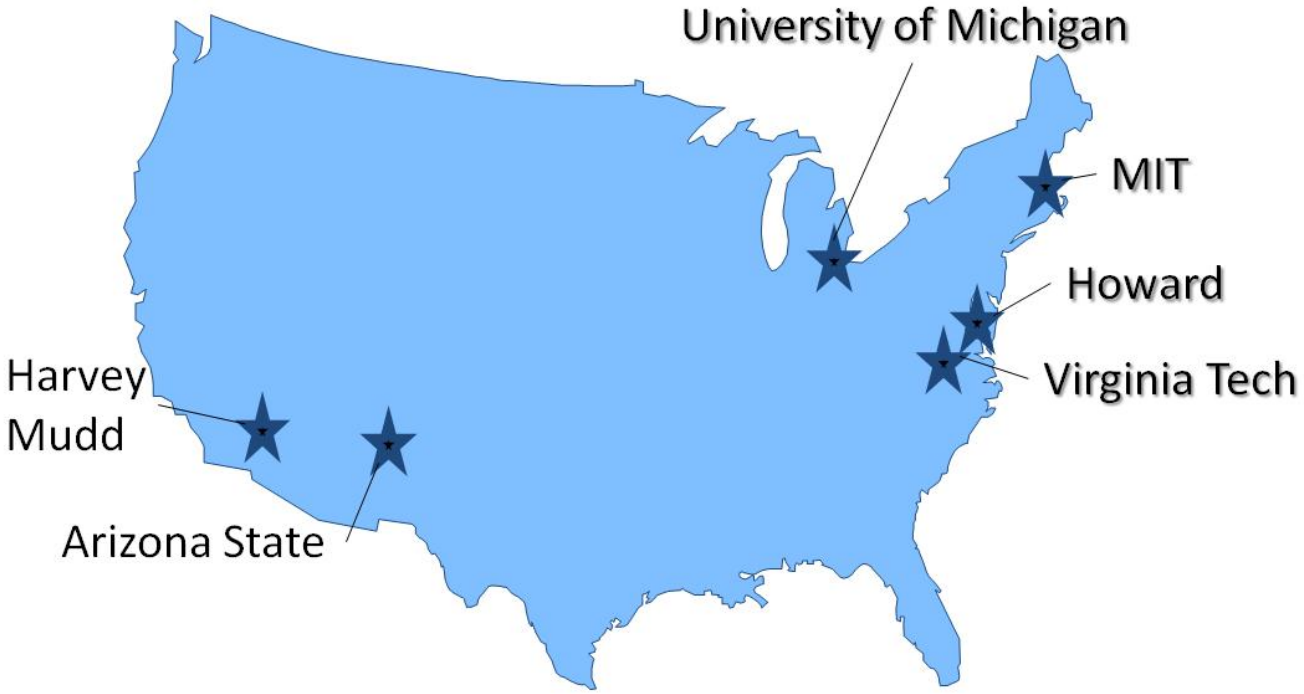
- Empirically identified engineering schools out-performing others in:
  - producing graduates who resemble the engineer of 2020
  - attracting and graduating women and underrepresented students
- Conducted case studies of curricula, pedagogy, faculty culture, and internal policies and procedures promoting student outcomes

Conceptual Framework

(Adapted from Terenzini and Reason, 2005)



P360 Case Study Sites



Institution	Administrators	Faculty	Students	Other	TOTAL
Arizona State University	24	33	21		78
Harvey Mudd College	11	20	24	7	62
Howard University	12	28	62		102
MIT	20	17	16		53
University of Michigan	27	31	45		103
Virginia Tech	11	30	21	8	70
TOTAL	105	159	189	15	468

Focal Outcomes Definitions

Interdisciplinary Competence

The ability to draw upon and integrate knowledge and perspectives from different disciplines, both in **and** outside engineering

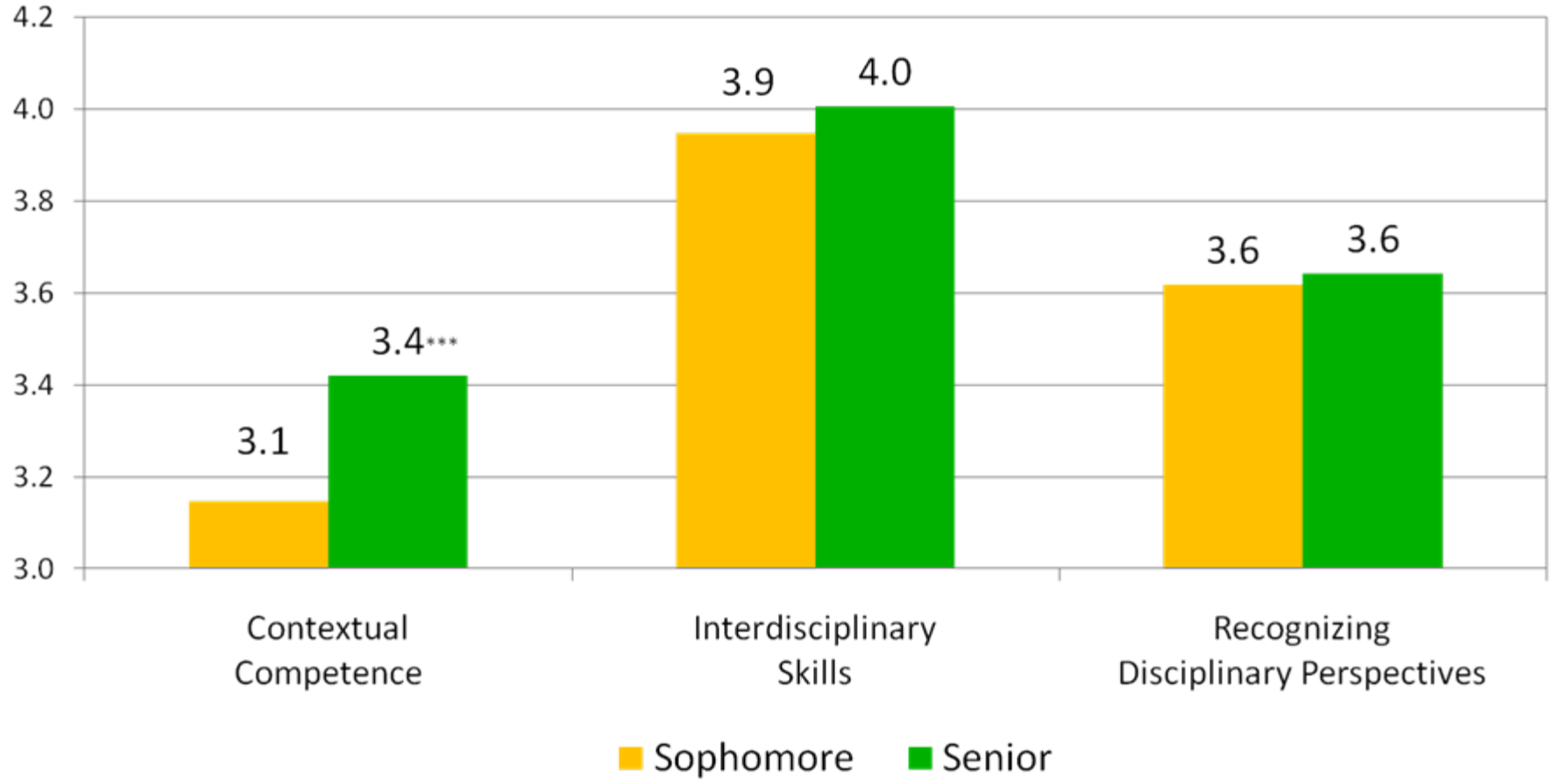
Contextual Competence

The awareness

- of the environmental, social, economic, and political factors that influence the design of engineering solutions, and
- that engineering solutions also influence contexts

Student Learning Outcomes (P2P Study)

Student Learning Outcomes: Sophomores versus Seniors



3 = Good ability; 4=Very good; 5 = Excellent

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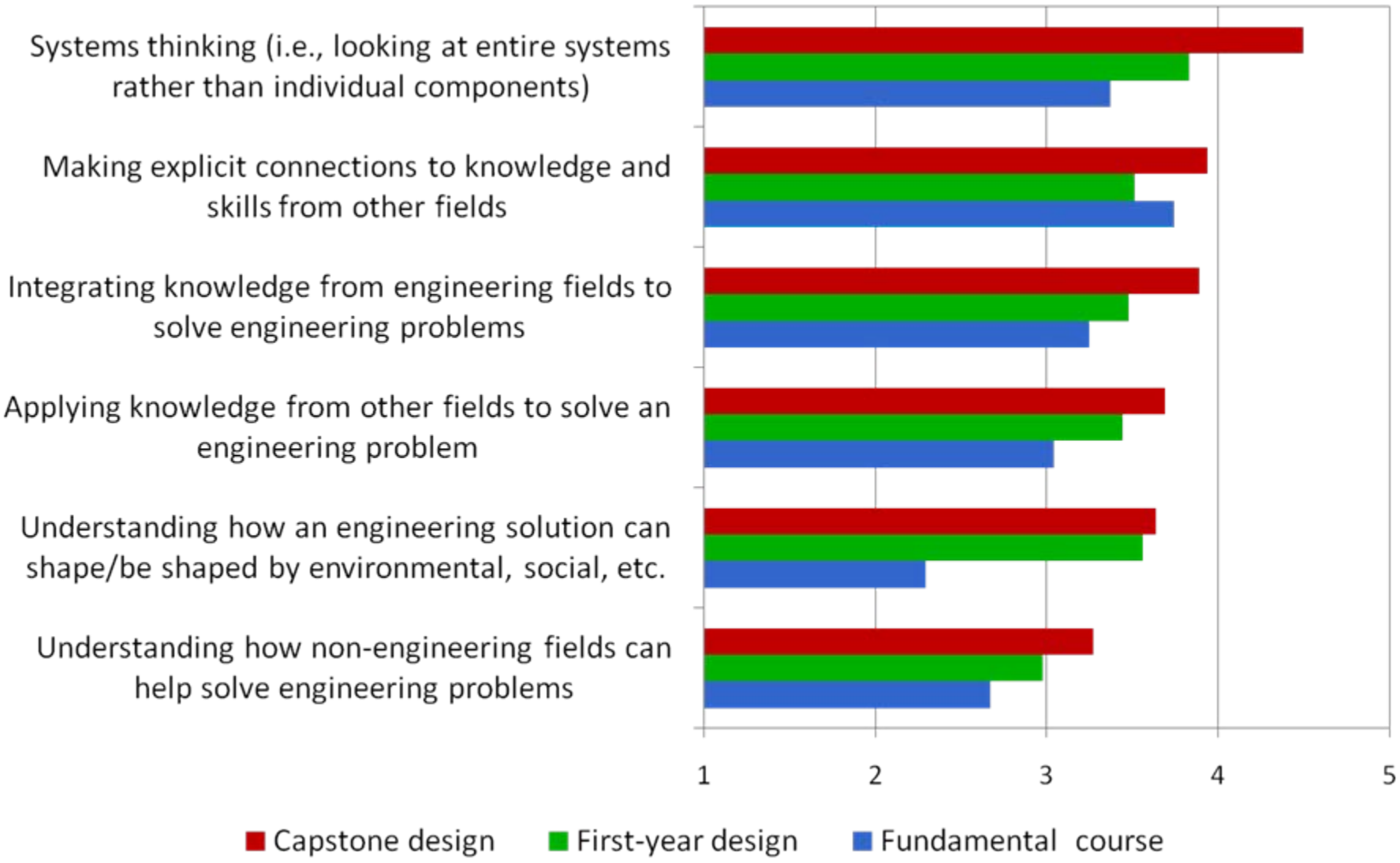
Curricular Influences

Faculty Emphasis On:



1=Little/no emphasis; 2=Slight; 3=Moderate; 4=Strong 5=Very strong emphasis

Interdisciplinary Skills
Nature of Design Courses

	Students only from program	Students from different engineering fields	Students from non-engineering fields	Design course not offered
First Year Design	24%	28%	6%	22%
Second Year Design	23%	12%	0%	40%
Third Year Design	48%	10%	0%	26%
Fourth Year Design	71%	22%	4%	0%

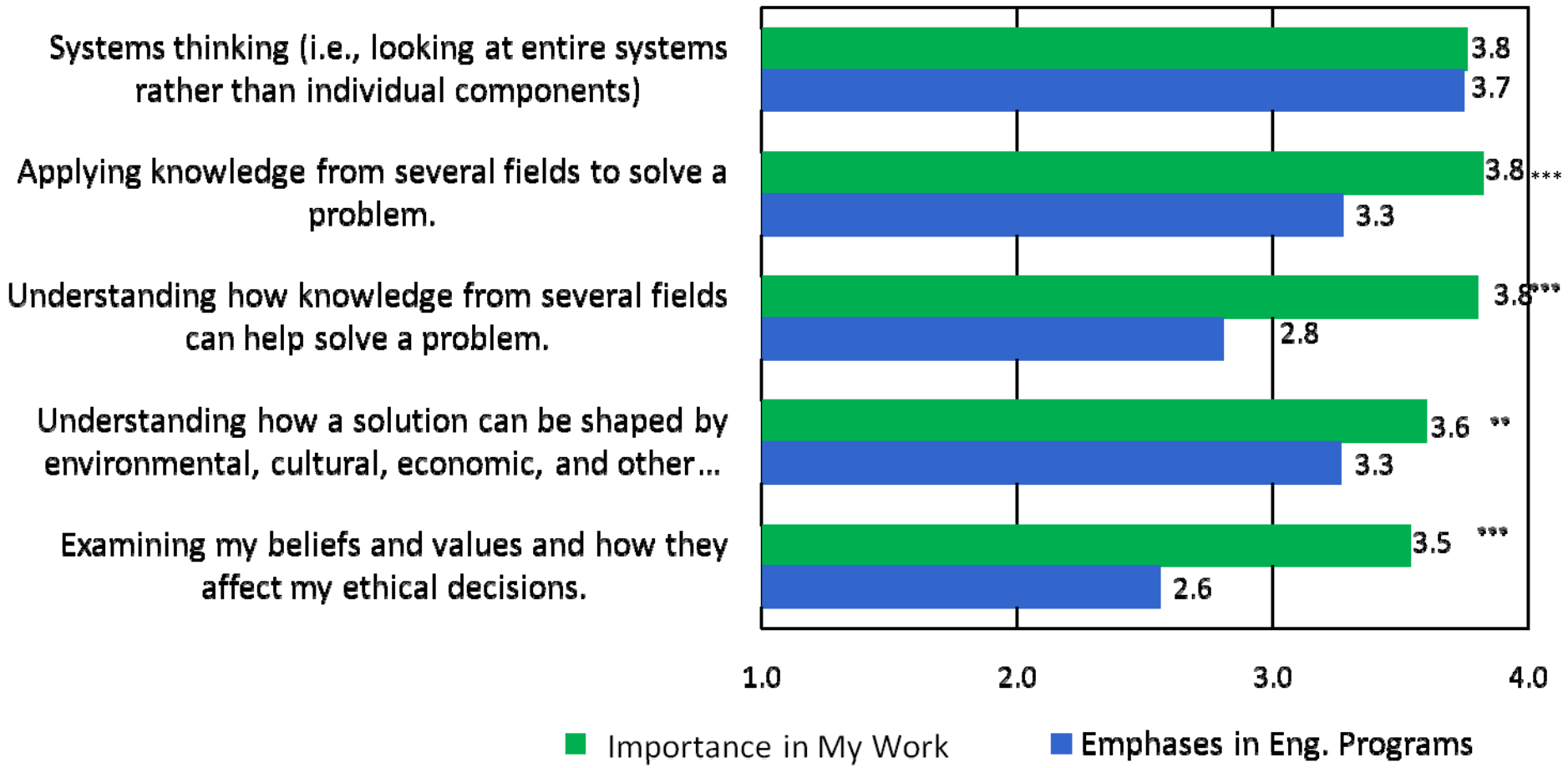
Values represent percentages of program chairs in sample.

P360 Interviews: Clarifying Interdisciplinarity

- Faculty and administrators used the terms “interdisciplinary” and “multidisciplinary” differently – often interchangeably
- Ambiguity existed both within and across programs and schools
- ABET Criterion 3.d – multidisciplinary teamwork
  - Tends to be defined as “within engineering”
  - And focused on teamwork rather than knowledge development
- Students may be rating their multidisciplinary teamwork skills rather than their “interdisciplinary” skills
- Participants’ discussions of multi- and interdisciplinary learning activities suggested different student learning objectives
  - What is learned will vary depending on type of activity
  - Need greater clarity in learning objectives and course design

Curricular Emphases:

Importance in My Work (alumni) vs. Emphasis in Engineering Programs (program chairs)



A: 1=Little/none; 2=Slight; 3=Moderate; 4=High; 5=Very high

PC: 1=Little/no emphasis; 2=Slight; 3=Moderate; 4=Strong 5=Very strong emphasis

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Case Study Findings:
Promoting Interdisciplinary Competence

- General Engineering programs
  - ***ASU-Poly and HMC***: emphasized project-based and hands-on learning and interdisciplinary connections throughout the curriculum
- General education requirements
  - ***HMC***: Common core requirements and integrative studies courses
  - Humanities/social sciences concentration and advisor
- Multidisciplinary majors and minors
  - ***MIT:*** Students affiliate with a degree program, but take courses in whichever program interests them
  - ***UM***: "Pull" from students for multidisciplinary design experiences
- Interdisciplinary options in select courses
  - ***HU***: Senior design teams paired with industry sponsors
  - ***VT***: Interdisciplinary teams required in courses for multiple majors

Curricular Influences on Contextual Competence

- Related to interdisciplinary efforts to integrate content
  - Intentional curriculum design
  - Individual instructors choose to include it
- Design courses
  - First Year (e.g., VT's ethics, sustainability, communication, global awareness)
  - Capstone: Several institutions linked these directly to industry
- Strong (or emerging) emphasis on global contexts
  - ***UM***: International Minor in Engineering
  - ***HMC***: Global Clinic
  - ***ASU***: Office for Global Engagement (engineering-specific)
- Growing emphasis on entrepreneurship

Curricular Influences on Interdisciplinary & Contextual Competence

- Strongest predictor is curricular emphasis on *Broad and Systems Perspectives* (P2P data)
  - Understanding how non-engineering fields can help solve problems
  - Applying knowledge from other fields to solve an engineering problem
  - Understanding how an engineering solution can be shaped by environmental, cultural, economic, and other considerations
  - Systems thinking (i.e. looking at entire systems rather than individual components)

- Emphasis varied across disciplines
  - ***High***: Industrial and biomedical/bioengineering
  - ***Middle***: General, civil engineering
  - ***Low***: Electrical, chemical, and mechanical engineering

Curricular Influences on Contextual Competence

- Curricular emphasis on *Core Engineering Thinking* is also a predictor of contextual competence
  - Generating and evaluating ideas about how to solve a problem
  - How theories are used in engineering practice
  - Emerging engineering technologies
  - Defining a design problem
  - Creativity and innovation

Co-Curricular Influences

Co-Curricular Influences on Interdisciplinary & Contextual Competence

- Design competitions
  - All campuses noted these as important for skill development
  - Hands-on, industry-related projects
- Undergraduate research opportunities
- Activities focused on entrepreneurship, sustainability, and humanitarian engineering projects
- Important: support from institution in terms of resources and faculty

Co-Curricular Influences on Interdisciplinary Skills

- Positive influences on interdisciplinary skills:
  - Undergraduate research
  - Internship
  - Humanitarian engineering projects
  - Student design competitions
  - Non-engineering clubs and activities

- Negative influences on interdisciplinary skills:
  - Student chapters of professional societies

Co-Curricular Influences on Contextual Competence

- Positive influence on contextual competence:
  - Engineering-related organizations for women/minority students
  - Humanitarian engineering projects
  - Non-engineering service activities
  - Non-engineering-related clubs and activities

- Unrelated activities to contextual competence:
  - Student chapters of professional societies
  - Study abroad opportunities

Disciplinary Variation in Co-Curricular Participation

Students in different disciplines tend to participate in different activities

- ***Biomedical/bioengineering***:
  - Undergraduate research
  - Community service
- ***General engineering***:
  - Study abroad
  - Humanitarian engineering projects
- ***Civil, mechanical, industrial***: Cooperative education
- ***General, biomedical/bioengineering, electrical***: Design competitions

Influence of Student Precollege Characteristics on Interdisciplinary & Contextual Competence

- Strong predictor of both outcomes: SAT critical reading score
  - Mathematics skills are the foundation for problem solving and design
  - Critical thinking and analogical reasoning may be the building blocks for interdisciplinary skills and contextual competence

- Experiences in engineering programs matter **net of** precollege characteristics

Challenges to Developing Interdisciplinary & Contextual Competence

"Let's say that many of my colleagues feel that for them to instruct in this area is a waste of their professional time."

"Where once we hoped that our graduates would analyze thermodynamic efficiency, now our graduates must also help analyze the ethical and social impacts of their technologies."

Challenges Common across Case Study Sites

- Inflexibility of the engineering curriculum
- Tension between contextual and technical skills
- Variations in perceptions of relevance across disciplines
- Available resources to support the co-curriculum
- Different conceptions of interdisciplinary and contextual competence

E2020 Studies
http://www.ed.psu.edu/educ/e2020

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Preparing the Engineers of 2020

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Influence of Institutional Contexts

Context Matters

Arizona State

Location allows strong industry connections; Michael Crow's "New American University"

Harvey Mudd

Founders stressed interdisciplinarity and contextual competence in mission statement, which is known by all members of the university

Howard

As an HBCU, focused on educating local, national, and global leaders within a community historically excluded from leadership positions

Michigan

Farsighted administrators and faculty leaders in engineering & campus-wide

MIT

Highly academically prepared and motivated student body demands the inclusion of interdisciplinary and contextual issues

Virginia Tech

Land Grant university with strong military past led to practical focus