



Transforming Undergraduate Education in Engineering
Phase II: Insights from Tomorrow's Engineers

Pre-meeting Survey Summary Report

March 2015

American Society for Engineering Education

The logo for TUEE (Transforming Undergraduate Education in Engineering) is located in the top left corner. It features the letters 'TUEE' in a bold, dark green font. To the right of the logo, the text 'Transforming Undergraduate Education in Engineering' is written in a smaller, dark green font. Below this, the title 'Phase II: Insights from Tomorrow's Engineers' is displayed in a larger, bold, dark green font. The background of the top left corner is filled with various icons related to engineering and technology, such as a computer monitor, a gear, a lightbulb, and a person, all in a light green color.

TUEE Transforming Undergraduate Education in Engineering

Phase II: Insights from Tomorrow's Engineers

Pre-workshop Survey Results

In preparation for the *Insights from Tomorrow's Engineers* workshop, 165 students were invited to complete a survey on what they consider the most important *Knowledge, Skills and Abilities* (KSAs) for engineering, the perceived quality of preparation in these areas, and their curricular and extra-curricular experiences to develop such KSAs. With 81% response rate, survey respondents represent diverse fields of engineering, demographic diversity of the student body, institutional diversity and geographical location.

Summary of Responses to Closed-ended Questions

The thirty-six KSAs defined in Phase I by industry were presented to engineering students in the pre-workshop survey. Students were asked to rank the importance of each of the KSAs to the engineering profession as they perceived it. Additionally, they were also asked to rank the importance of each KSA as it is currently conveyed to them by their institution, as well as the quality of education they are currently receiving in each respective KSA area. The reported results for each of the 36 KSAs are listed in Table 1, divided into three sections consisting of 12 KSAs each. The table shows many areas in which students as well as academia and the curriculum are closely aligned in their perception of importance. It also highlights areas of discrepancies where students and academia perceive the importance of certain KSAs differently. More importantly, Table 1 indicates which areas of engineering education lack quality and where updates and improvements may be needed.

Table 2 cross-tabulates results from the student pre-meeting survey with data gathered from industry in Phase 1, juxtaposing the importance of each KSA for the engineering profession as perceived by students and industry not only in the present, but also by industry in the next decade. Overall, the comparative data in the table shows a tendency for students to be more closely aligned with what industry perceives will be important in the next decade, compared to industry's priorities today.

Summary of Responses to Open-ended Questions

A widespread view held among the sample of students surveyed revealed that, in their eyes, engineering classes tend to focus largely on the technical aspects of engineering and not so much on how engineers interact in a multidisciplinary and interconnected workforce. While the concrete scientific principles of engineering are absolutely necessary, being able to interact with others and apply knowledge and education to multiple areas of life is crucial for the success of the engineering professional. Generally, fundamental engineering and science classes do stress the importance of **critical thinking, working in teams, prioritizing**, and finding unique ways to **solve problems**. Varying from institution to institution, and depending on the individual professors and their backgrounds, the engineering curriculum also often includes coursework and opportunities to build other important professional KSAs such as **communication, leadership, and system integration skills**, as well as a level of understanding of **economics, business, and public safety**.

According to students, however, hardly any one university teaches the theory of engineering better than another, and it's unlikely that curriculum and theory alone could make a noticeable difference in the quality and preparedness of engineering graduates. In the absence of the 'soft skills' to understand context, identify critical problems, connect the dots, and influence others, theory and technical skill become far less valuable. Ideally, engineers must take classes that will provide them with a **holistic education** in addition to prolific technical expertise. In the eyes of numerous students, what does make a difference in engineering education is the mix of classwork, practical assignments, and extracurricular activities that prepare students across the board of KSAs. These shape them into members of the workforce and society who bring **strong values, a broad perspective, leadership**, the ability to **communicate** with engineers and non-engineers alike, and **quality work and products** that tackle real-world problems.

Going beyond hard science and engineering fundamentals in the curriculum, it is important for engineering education to focus on developing the more abstract KSA areas—the soft skills that would help students learn how to apply their education into real life and adapt to engineering workforce situations. According to students, as central as these soft skills are, many are difficult to teach academically. Therefore, it comes down to extracurricular activities, teamwork, and students' own motivation to develop a lot of the softer KSAs.

Project-based learning and opportunities such as design projects, capstones, lab work, research projects, co-ops and internships, membership in professional societies and student organizations, conferences, competitions, and seminars every single year of school build upon the scientific theory. They also bridge **technical knowledge** with **applied skills** in industries, society, and the real world, introducing a great variety of necessary skills not covered by the curriculum. They set students up for professional success. Such multidisciplinary teamwork activities combine project-based learning and extracurricular work to develop some of the most important soft skills students will need throughout their engineering program and beyond: **leadership, teamwork, communication, time management, prioritization, critical thinking, problem-solving, adaptability, entrepreneurship, self-drive, curiosity, creativity, and risk-taking**. Classes that don't have a syllabus, but consist of semester-long student-directed project work without a set schedule of checkpoints could serve as a real incubator for these crucial soft skills.

Design projects and competitions, student design clubs, and capstones were frequently highlighted as prime examples of project-based learning that allowed students to apply their theoretical knowledge in practice and acquire additional vital skills through hands-on engineering work. For instance, one

surveyed institution requires their seniors to take a year-long senior engineering design course. This course stresses all of the first 12 KSAs and more. In the course, students work in **teams** of 4-5 student members to **design** a product for a local sponsoring company that **solves a real-life engineering problem**. They work with a faculty advisor and liaison engineer(s) from the sponsoring company throughout the year in **product development**. Throughout the course, students **prepare a proposal**, create and follow a **project budget**, **communicate** with necessary stakeholders, **apply fundamental engineering principles**, and inquire about further knowledge necessary to create a solution to the presented engineering problem. **Students present finished products** at the end of year to the university, sponsoring companies, and the general public in the form of a 20-minute formal presentation, as well as a poster session. Other engineering departments specifically assign design projects at the end of every semester, very much like a senior design course, to help prepare students for engineering tasks, instead of focusing on exams. Furthermore, extracurricular activities such as **volunteering** with Engineers Without Borders allow students to apply the academic concepts they learn in their classes to projects that have real-world impact. It's an opportunity for aspiring engineers to go through the **entire project cycle**, from concept-generation to financial management, component design, systems integration, and construction on the ground, while at the same time developing strong **communication skills** and **cultural understanding** amongst diverse communities.

One of the students provided another illustration of the benefits of design projects when they recounted their experience with a Formula SAE car. Almost none of the new members to the Formula team initially had knowledge of what goes into the cars. Because of this, experienced members **mentored** others to ensure that knowledge was passed down through the team, and that a larger group was available for **problem solving**. Ultimately, these new members grew into **leadership** roles during their junior or senior years, which provided exposure to additional lessons, and **mentorship** and knowledge continuity. Furthermore, with any leadership role there is a degree of **accountability**, along with the ability to create and lead the **design and vision**. Students were able to work with one another to apply their pre-existing knowledge to the **design and fabrication** of the car, along with its testing and maintenance. Ultimately, through the mentorship and **applied knowledge**, students and instructors saw **innovation** in every car. The team was able to work together through not only the engineering and design challenges, but also through **conflict resolution**, thus building **interpersonal skills** and **emotional intelligence**. As a whole, the experience in Formula SAE provided students not only access to technology and applied engineering knowledge to tackle problems, but also the experience of working with others on a human level.

Overall, many students agreed that freshman and sophomore years of college engineering tend to focus on the fundamental. The much-needed soft skills, context, and practical project and design opportunities only come during the junior and senior years. Students believe that in order to create modern and well-prepared engineers, classes and extracurricular activities should focus on both hard science and soft skills simultaneously from the very beginning and continue throughout the entire degree. At the same time, fundamental scientific concepts and core soft skills should have continuous refreshers so they don't fade away. These could be established and applied in practice. Moreover, applied project design assignments should be attached at the end of each course in engineering school, not just as senior design class in senior year.

Multidisciplinary learning experiences can also be instrumental in teaching students a diverse range of KSAs. The students highlighted a particular multidisciplinary engineering program as an example. The program is running a minor in engineering leadership development where business, education, and engineering majors are able to work together in culturally and professionally diverse teams on projects

that teach **leadership, business fundamentals** (finances, budgets, project proposals, and business plans), **technical presentations, ethics, global perspective, cultural awareness**, and how they all connect to the field of engineering to **solve societal needs**. Some schools also require students to take an engineering clinic every semester. The clinic is a class where students work in a **team on a multidisciplinary research-based project**. This helps cultivate **curiosity** and a persistent desire for **continuous learning**, along with **self-drive** and **motivation**. During the clinics, students learn a lot about not just **economics**, but also **ethics** and **integrity** by researching and presenting an engineering ethics case. This teaches students about high ethical standards, integrity, and global, social, intellectual, environmental, and technological responsibility.

Extracurricular activities such as involvement in, or leadership of, project management (design, lab, capstones, etc.), student clubs and organizations, student chapters of professional societies, and community work are also highly effective in developing KSAs. These can cultivate strong **leadership, teamwork, management and communication skills, self-motivation, critical thinking, problem-solving, and system thinking and system integration** abilities. All of these activities involve working with a number of different stakeholders, ranging from executives to volunteers, full-time staff, administration, and external groups. Extracurricular activities could also be multidisciplinary, providing opportunities to work with peers from other majors.

Figure 1: Student participants by field of study

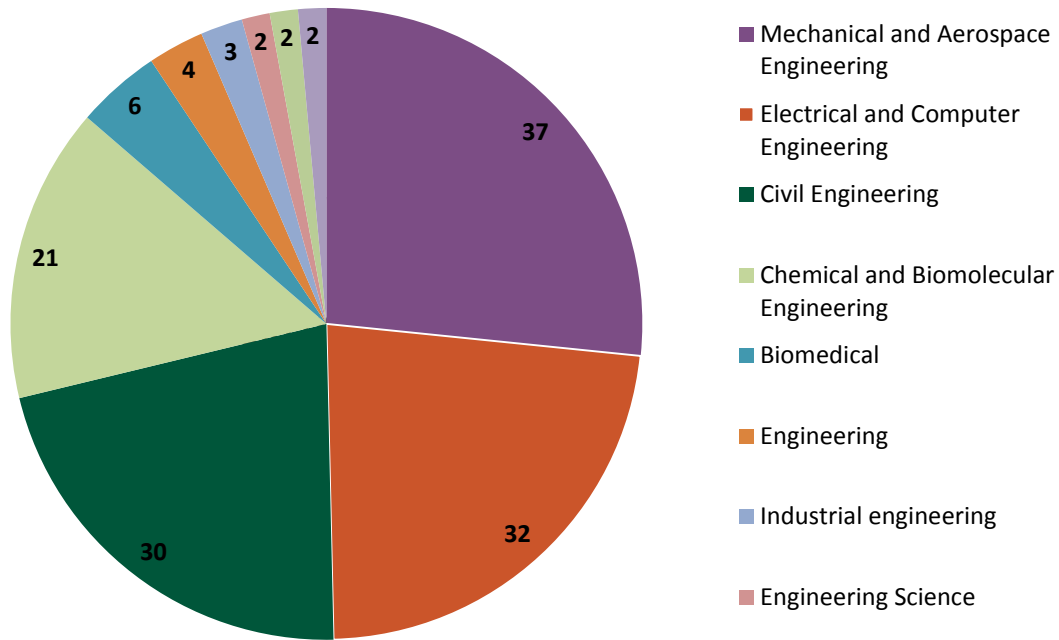
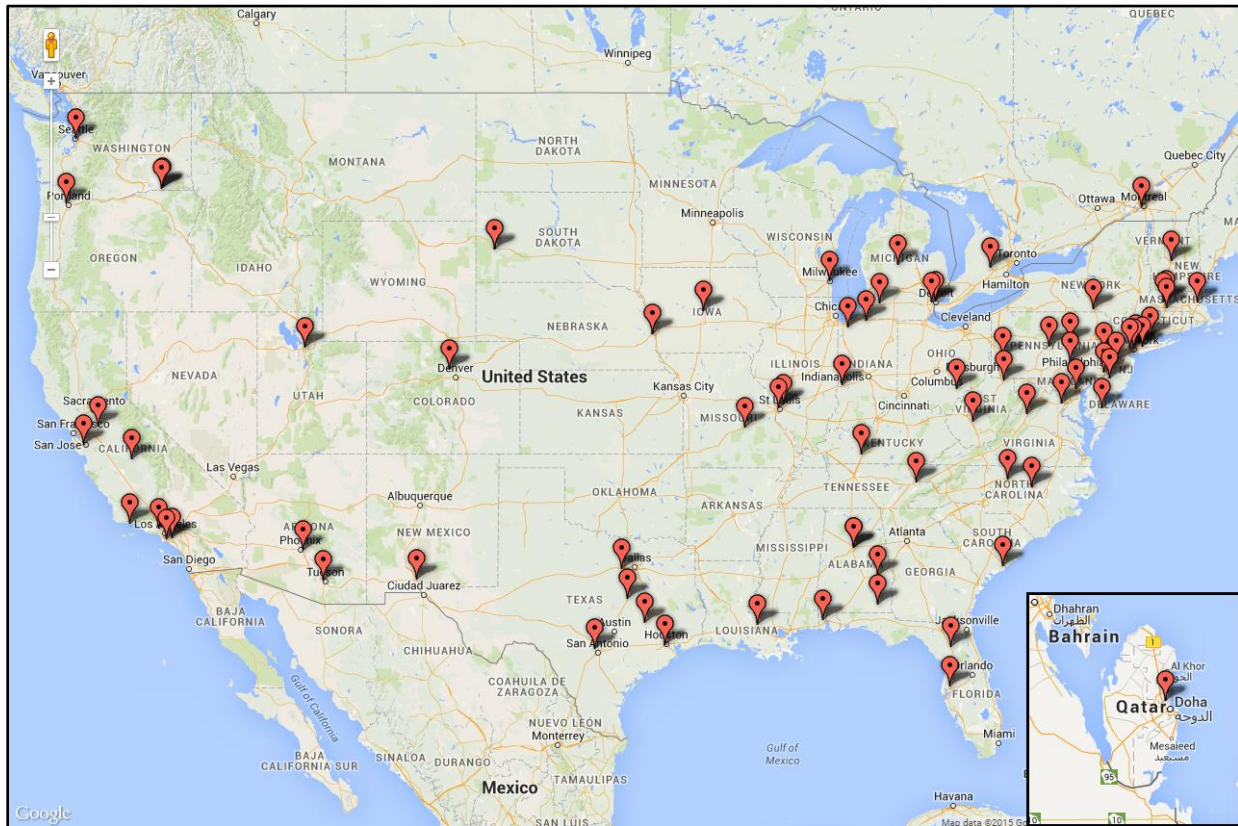


Figure 2: Student participants by location of their institution



Participant Institutions

Arizona State University
Baylor University
Bucknell University
California State University, Fresno
California State University, Fullerton
California State University, Northridge
Central Michigan University
Concordia University
Dartmouth College
Embry-Riddle Aeronautical University
Exergy Controls
Fairfield University
George Mason University
HDR Inc.
Iowa State University
James Madison University
Johns Hopkins University
Lehigh University
Manhattan College
Missouri University of Science and Technology
New Mexico State University
New York Institute of Technology
NJIT / H2M Architects + Engineers
North Carolina A&T State University
North Carolina State University
Northeastern University
Ohio University
Pennsylvania State University
Pennsylvania State University, Harrisburg
Qatar University
Rice University
Rose-Hulman Institute of Technology
Rowan University
Saint Louis University
Santa Clara University
Seattle University
Smith College
South Dakota School of Mines and Technology
Southern Illinois University, Edwardsville

Southern University A&M College
State University of New York, Binghamton
Stevens Institute of Technology
Swarthmore College
Texas A&M University
Texas Christian University
The Citadel
The College of New Jersey
Tulane University
Tuskegee University
University of Alabama, Birmingham
University of Arizona
University of California, Santa Barbara
University of Colorado, Boulder
University of Delaware
University of Florida
University of Massachusetts, Amherst
University of Michigan, Dearborn
University of Notre Dame
University of Pittsburgh
University of Portland
University of South Alabama
University of South Florida
University of Tennessee, Knoxville
University of Texas, San Antonio
University of the Pacific
University of Utah
University of Waterloo
US Army Corps of Engineers, Walla Walla District
Valparaiso University
Walla Walla University
Wayne State University
We Energies
West Virginia University
West Virginia University Institute of Technology
Western Kentucky University
Western Michigan University
Western New England University

Table 1. Students' perceptions of KSAs' importance for the engineering profession and quality of education received in each area

| Knowledge, Skills and Abilities (KSAs) ¹ | A. Importance for the engineering profession | | | | | | | | B. Quality of education ⁴ | | | |
|---|--|--------------------------------------|----------------------------------|--------------------------------------|----------------------------------|--------------------------------------|----------------------------------|--------------------------------------|--------------------------------------|-----|------|-----|
| | Very Important* | | Moderately Important | | Unimportant ** | | Not sure | | VG-G | F | P-VP | NS |
| | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | | | | |
| KSA 1: Good communication skills | 100% | 82% | 0% | 16% | 0% | 2% | 0% | 0% | 44% | 43% | 13% | 1% |
| KSA 2: Hard sciences and engineering science fundamentals | 90% | 96% | 8% | 3% | 2% | 1% | 0% | 0% | 46% | 46% | 7% | 1% |
| KSA 3: Ability to identify, formulate, and solve engineering problems | 99% | 94% | 1% | 6% | 0% | 1% | 0% | 0% | 48% | 40% | 12% | 0% |
| KSA 4: Systems integration | 79% | 44% | 12% | 40% | 1% | 9% | 8% | 8% | 10% | 38% | 39% | 13% |
| KSA 5: Curiosity and persistent desire for continuous learning | 96% | 58% | 4% | 29% | 0% | 12% | 0% | 1% | 35% | 39% | 25% | 1% |
| KSA 6: Self-drive and motivation | 99% | 62% | 1% | 27% | 1% | 11% | 0% | 0% | 32% | 38% | 30% | 1% |
| KSA 7: Cultural awareness in the broad sense (nationality, ethnicity, linguistic, gender, sexual orientation) | 68% | 41% | 24% | 37% | 6% | 19% | 2% | 2% | 29% | 33% | 30% | 9% |
| KSA 8: Economics and business acumen | 71% | 36% | 28% | 42% | 1% | 19% | 0% | 2% | 10% | 48% | 39% | 4% |
| KSA 9: High ethical standards, integrity, and global, social, intellectual, and technological responsibility | 99% | 86% | 1% | 9% | 0% | 5% | 0% | 0% | 46% | 40% | 12% | 1% |
| KSA 10: Critical thinking | 98% | 91% | 2% | 9% | 0% | 0% | 0% | 0% | 43% | 44% | 12% | 1% |
| KSA 11: Willingness to take calculated risk | 76% | 37% | 20% | 40% | 3% | 17% | 1% | 7% | 12% | 42% | 37% | 9% |
| KSA 12: Ability to prioritize efficiently | 95% | 70% | 5% | 25% | 0% | 4% | 0% | 1% | 32% | 51% | 16% | 1% |

Note. N=141

¹ KSAs are ordered by priority as initially defined by industry representatives at the TUEE Phase I Workshop, see report at http://www.asee.org/TUEE_PhaseI_WorkshopReport.pdf

² Level of importance as perceived by students.

³ Level of importance communicated to students through orientation, advising, classes and other activities at their institutions.

⁴ Quality of curricular and extra-curricular activities to help develop each area.

VG-G = very good/good; F = fair; P-VP = poor/very poor; NS = Not Sure

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|--|--|--------------------------------------|----------------------------------|--------------------------------------|----------------------------------|--------------------------------------|----------------------------------|--------------------------------------|--------------------------------------|-----|------|-----|
| | Very Important* | | Moderately Important | | Unimportant ** | | Not sure | | VG-G | F | P-VP | NS |
| | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | | | | |
| KSA 13: Project management (supervising, planning, scheduling, budgeting etc.) | 93% | 74% | 6% | 17% | 2% | 10% | 0% | 0% | 37% | 37% | 26% | 1% |
| KSA 14: Teamwork multidisciplinary work | 99% | 93% | 1% | 10% | 0% | 2% | 0% | 0% | 58% | 31% | 10% | 0% |
| KSA 15: Entrepreneurship and intrapreneurship | 61% | 39% | 33% | 39% | 5% | 20% | 2% | 2% | 20% | 31% | 46% | 3% |
| KSA 16: Use new technology and modern engineering tools necessary for engineering practice | 93% | 69% | 7% | 21% | 0% | 10% | 0% | 1% | 19% | 47% | 32% | 2% |
| KSA 17: Public safety | 97% | 85% | 2% | 12% | 0% | 2% | 1% | 2% | 33% | 47% | 15% | 6% |
| KSA 18: Informational technology (IT) | 67% | 48% | 26% | 34% | 5% | 15% | 2% | 4% | 5% | 53% | 32% | 10% |
| KSA 19: Applied knowledge of engineering core sciences for the real world | 91% | 88% | 7% | 7% | 1% | 4% | 1% | 2% | 40% | 42% | 18% | 1% |
| KSA 20: Data interpretation and visualization | 92% | 78% | 7% | 18% | 0% | 4% | 1% | 1% | 29% | 45% | 25% | 2% |
| KSA 21: Security knowledge (cyber, data, etc.) | 66% | 31% | 22% | 36% | 12% | 27% | 1% | 7% | 8% | 32% | 52% | 8% |
| KSA 22: Leadership | 99% | 77% | 1% | 18% | 1% | 5% | 0% | 0% | 47% | 36% | 17% | 1% |
| KSA 23: Creativity | 95% | 58% | 5% | 32% | 0% | 9% | 0% | 1% | 26% | 42% | 31% | 0% |
| KSA 24: Systems thinking | 78% | 58% | 9% | 19% | 2% | 8% | 12% | 15% | 17% | 37% | 30% | 16% |

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| | Very Important* | | Moderately Important | | Unimportant ** | | Not sure | | VG-G | F | P-VP | NS |
| | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | Personal perception ² | Conveyed by Institution ³ | | | | |
| KSA 25: Emotional intelligence | 72% | 29% | 20% | 34% | 6% | 29% | 3% | 10% | 14% | 36% | 32% | 19% |
| KSA 26: Application based research and evaluation skills | 86% | 77% | 11% | 17% | 1% | 4% | 1% | 2% | 41% | 38% | 15% | 6% |
| KSA 27: Ability to create a vision | 85% | 49% | 10% | 30% | 2% | 16% | 3% | 4% | 17% | 44% | 34% | 4% |
| KSA 28: Good personal and professional judgment | 99% | 78% | 1% | 17% | 0% | 4% | 0% | 1% | 39% | 43% | 17% | 1% |
| KSA 29: Mentoring skills | 86% | 51% | 12% | 25% | 2% | 22% | 0% | 2% | 31% | 44% | 23% | 2% |
| KSA 30: Flexibility and the ability to adapt to rapid change | 98% | 68% | 2% | 25% | 0% | 7% | 0% | 0% | 28% | 43% | 28% | 1% |
| KSA 31: Ability to deal with ambiguity and complexity | 95% | 81% | 3% | 15% | 1% | 3% | 1% | 1% | 36% | 41% | 21% | 3% |
| KSA 32: Innovation | 92% | 77% | 7% | 17% | 0% | 5% | 1% | 2% | 34% | 36% | 29% | 2% |
| KSA 33: Technical intuition (metacognition) | 78% | 66% | 15% | 20% | 1% | 3% | 7% | 12% | 19% | 50% | 17% | 15% |
| KSA 34: Understanding of design | 97% | 91% | 3% | 7% | 0% | 1% | 0% | 1% | 38% | 49% | 12% | 1% |
| KSA 35: Conflict resolution | 94% | 60% | 7% | 25% | 0% | 14% | 0% | 1% | 28% | 41% | 28% | 3% |
| Q36: Ownership and accountability | 98% | 83% | 1% | 14% | 0% | 2% | 1% | 1% | 43% | 39% | 15% | 3% |

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Table 2. Industry vs. Students: Perceptions of the importance of high priority* KSAs for the engineering profession**

| Knowledge, Skills and Abilities (KSAs) | Very Important | | | Moderately Important | | | Unimportant | | |
|---|----------------|------------------|------------------|----------------------|------------------|------------------|-------------|------------------|------------------|
| | Students | Industry in 2013 | Industry in 2023 | Students | Industry in 2013 | Industry in 2023 | Students | Industry in 2013 | Industry in 2023 |
| Good communication skills | 100% | 81% | 84% | 0% | 19% | 16% | 0% | 0% | 0% |
| Hard sciences and engineering science fundamentals | 90% | 53% | 51% | 8% | 46% | 48% | 2% | 2% | 2% |
| Ability to identify, formulate, and solve engineering problems | 99% | 75% | 88% | 1% | 25% | 13% | 0% | 0% | 0% |
| System Integration ¹ | 79% | 53% | 75% | 12% | 44% | 25% | 1% | 3% | 0% |
| Curiosity and persistent desire for continuous learning | 96% | 75% | 84% | 4% | 25% | 16% | 0% | 0% | 0% |
| Self-drive and motivation | 99% | 81% | 91% | 1% | 19% | 9% | 1% | 0% | 0% |
| Cultural awareness in the broad sense (nationality, ethnicity, linguistic, gender, sexual orientation) ² | 68% | 38% | 84% | 24% | 56% | 16% | 6% | 6% | 0% |
| Economics and business acumen | 71% | 44% | 59% | 28% | 56% | 41% | 1% | 0% | 0% |
| High ethical standards, integrity, and global, social, intellectual, and technological responsibility | 99% | 88% | 88% | 1% | 13% | 13% | 0% | 0% | 0% |
| Critical thinking | 98% | 81% | 88% | 1% | 19% | 13% | 0% | 0% | 0% |

*These high priority KSAs were initially selected by industry representatives at the TUEE Phase I Workshop, see report at http://www.asee.org/TUEE_PhaseI_WorkshopReport.pdf

**Percentage totals may exceed 100% due to rounding

¹ 8% of Students responded with 'Not Sure'

² 2% of Students responded with 'Not Sure'