Aligning Computing Education with Engineering Workforce Needs

CPACE Collaborative Process to Align Computing Education

2009 EXECUTIVE SUMMARY | BUSINESS AND INDUSTRY REPORT

Engineering Education and Workforce Skills Context

Industries and educational institutions across the country are experiencing huge workforce and economic challenges posed by a global economy. Skill requirements of jobs at all levels are changing rapidly, particularly in the science, technology, engineering, and mathematics (STEM) disciplines. This often translates into a need for advanced knowledge in a single science, engineering, or mathematics discipline, knowledge in a computational discipline, and the ability to apply new computational methods and concepts to solve problems. These rapid workforce and economic changes present challenges to job seekers, employers, educators, and workforce and economic development professionals.

In response to these economic conditions and computational needs, a two-year project was funded by the National Science Foundation (NSF) in the summer of 2007 called CPATH CB: Computing and Undergraduate Engineering: A Collaborative Process to Align Computing Education with Engineering Workforce Needs (CPACE) (http://cpace.egr.msu.edu). The CPACE project brings together Michigan State University (MSU) in partnership with Lansing Community College (LCC) and the Corporation for a Skilled Workforce (CSW), in a process to transform undergraduate computing education within engineering fields. This transformational collaborative process is intended to engage business, education and workforce stakeholders to identify the computational knowledge and skills that are essential for an engineering workforce in the 21st Century. By computational knowledge and skills, we are referring to the background needed by the engineering workforce who uses computers to help analyze and solve technical problems, design and test engineered artifacts, and model complex systems in the engineered world. The long-term goal of this effort is to increase communication between academic institutions and employers that will lead to better education for employees and greater information sharing and knowledge brokering. We hope that these efforts will lead to employees better prepared in the areas of computational problem-solving, independent thinking, creativity, and innovation. This report is intended to serve as feedback to the businesses that participated in the study as well as provide information to other businesses, industry groups, and the public at large.

Data

To identify the workforce computational skills the CPACE research team conducted interviews with 28 small to large public and private employers across various industries within Michigan and surveyed 181 employees working in these companies. The companies were selected to represent the business sectors, size and workforce distributions of a couple Michigan regions.

Findings

The data were analyzed to identify key issues that reflect the state of engineering and the talent pipeline related to the changing nature of engineering work and talent expectations. Our findings echo those expressed in the well known volume, The Engineer of 2020: Visions of Engineering in the New Century, published in 20045, by the National Academy of Engineering (NAE). This alignment indicates that our sample is reliable and that the results of our research on computing in engineering should be applicable to the national workforce. More detail about these findings and others are described further in the full report.

Core Jobs in Engineering are Changing

Workforce issues (recruiting, hiring and retaining talent) resonated as a critical engineering challenge - not just a human resource challenge. Throughout our research, employers consistently voiced their increasing expectation and desire for engineers who think holistically, irrespective of his or her engineering disciplinary training. This shift to a "holistic" engineer represents a fundamental shift in employer expectations. A second fundamental change over the last decade is the explosion of software which is changing both the computational and business nature of engineering work.

Talent Expectations

Our review of the data revealed several common – non-computational and computational – skill sets that employers expect of their engineering workforce.

Non-Computational Skill Set

- ***Soft skills highly valued.*** While key engineering skills and practices remains essential, employers and employees alike articulated the critical business imperative of interpersonal skills, communication and teamwork, what we term loosely here as "soft skills." In fact, needing interpersonal skills and/or general management skills emerged as one of the most common skill sets employees mentioned as an attribute they need to be successful in their job and one which they felt was not part of their formal educational experience.
- ***Increasing use of adaptive thinking.*** Similarly, employers expect their employees to engage in what we call "adaptive thinking." This perspective involves critical thinking, innovative thinking, and problem solving to conceptualize solutions or to determine root causes.
- ***Understanding the business context.*** Successful engineers, no matter their position in the company, enhance their productivity when they understand key business principles.

Computational Thinking Skill Set

For purposes here, we define computational thinking as using computers to analyze, design, model, problem solve, or make decisions as part of engineering practice. We categorized the computational skills uncovered in the research into four categories:

- ***Translate between conceptual and operational.*** The skills and mindset associated with adaptive thinking carries over into the ability to translate between the virtual and physical world. Successful engineers can understand and problem-solve both at the operational and conceptual level.
- ***Manage data to make meaning.*** This need to make meaning can be characterized as the important skill of data and information knowledge management skills. It is vital that engineers are able to both collect, organize, analyze and make meaning of the data and information and to be able to translate, broker, and share that information to others in a meaningful way.
- ***Comfort with multiple software and computational systems.*** Employers and students alike recognize that students will not learn, nor can the post-secondary educational system – either 4 year or 2 year institutions – teach, every software and computational system currently on the market. The important skill for the new engineer is the ability to quickly pick up on the relevant systems needed for the job.
- ***Using technology to increase business productivity.*** Employees and employers discussed the value of using software technologies such as virtual meetings, instant messaging, and collaborative tools that allow for real-time input on a global scale, to drive business productivity. In many firms, Microsoft Excel is considered a fundamental computational tool, mentioned more often than engineering specific software programs.

> One absolutely fundamental expectation that came through the interview process was employers' expectation that new hires will be able to apply basic computational concepts easily in a variety of settings.

Implications and Considerations

Our findings revealed that the changing nature of engineering work and the increased use of software represent a shift in needed computational skills. Employers' expectations for a more "integrated or holistic" engineer, the increasing importance of soft-skills, and the need for more project-based experiences in the classroom have a number of implications for change. Those implications and considerations are highlighted in the following three broad categories.

Growth of "green" engineering will impact all engineering disciplines and employers.

In addition to the "integrated" or holistic engineer concept, the other major engineering shift articulated by employers is the shift to "green." The push by consumers, the public sector and business for sustainable products and processes is impacting every industry. The implications for educational institutions are quite extensive, ranging from developing new curricula, updating curricula, and changing behavior. The curricula changes include potential impact on computational skills, such as new software programs and/or applying engineering principles to new innovations. Likewise, staff and customer expectations drive employers to improve both internal manufacturing processes and energy usage patterns. Across the board, these industry shifts suggest changing expectations by employers for what future hires should know about sustainability affect on computational engineering practices.

Employer actions to improve the talent pipeline.

1. ***Computational skills.*** Deepen and improve the feedback loop with curricula committees and faculty on computational skills and "adaptive thinking." This serves multiple purposes: providing faculty with real- world problems, providing students with "work like" projects, and building the university's knowledge of the "state of the art" trends and issues in various engineering fields.
2. ***Non-computational skills.*** Strengthen the feedback loop with educators about soft skills – both in career services AND in the curricula. The package of skills a student brings to a potential employer is what counts.

3. ***Employee orientation investment.*** Employee turnover is highest in the first year of employment. While mentoring is a critical first step many companies mentioned using, the more formalized employee orientation processes known as onboarding can dramatically improve productivity.

Universities/Community Colleges actions to improve the talent pipeline.

1. ***Computational skills.*** Project-based learning experiences should be embedded in the curriculum throughout all four years of the program. Some engineering educators are taking the approach of leveraging the knowledge and skills of the computer science department to help design real world problems suggested by industry for engineering students that emphasize engineering principles and computational skills. The result is a project that embeds computational skills in the engineering context.
2. ***Non-computational skills.*** Expanding cross-departmental collaboration represents another avenue to develop holistic or integrated engineers. Employers' emphasis on cross-discipline or integrated engineers reinforces the idea that engineers should have experience with various types of engineering, so that in their day to day jobs they can leverage others' expertise, add to their own, or make cross-functional connections.
3. ***Employer engagement.*** Proactively engaging and learning from employers as part of a comprehensive feedback loop can improve the fit between student's knowledge and experience and employer's talent expectations. Again, this feedback loop should also include faculty as well as career services.

Conclusion

Our findings reveal that employers a) place a high value on soft skills such as communication, project management, and the ability to function in a team; b) view "adaptive thinking" – the bundle of critical and innovative thinking and problem solving – as a key attribute; c) see trends towards computational globalization which translates to the need for engineers to understand business practices and the importance of integrating engineering data across larger systems; and d) place a high value on the ability of engineers to understand both engineering and computational principles that allow them to use computational tools to solve engineering problems by moving between abstractions in software and physical systems. The findings paint the picture of the emerging "holistic or integrated" engineer who brings core computational skills to his or her engineering work and leverages that knowledge within the business context. In many ways, the challenges facing the engineering profession are echoed in questions related to our overall economic prosperity. For instance, how will our workforce address the critical challenges facing all of us – decreasing the use of carbon, providing products and services in a sustainable way, and innovating new techniques? This question and others like it, reveal the fundamental nature engineering plays in our economic development. We hope that the results of our research showcase a way for educators and industry to come together to envision the future of the engineering workforce, and in turn, help imagine our future. ■

For more details about how you can get involved in sustaining this transformative engineering education and workforce effort, please go to http://cpace.egr.msu.edu to obtain a copy of the full report. Principal Investigator for CPACE, Associate Dean of Engineering, Thomas Wolff, may also be reached at wolff@msu.edu