ENGINEERING Education & Practice

How People Learn Engineering

# Connecting On-the-Job Problem Solving to the Engineering Classroom

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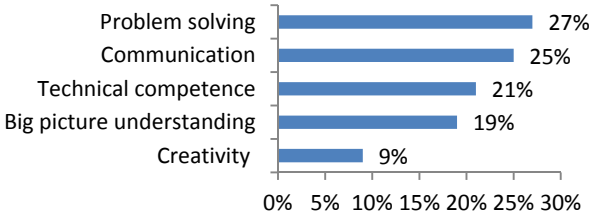
Through the course of a four year NSF project, we interviewed over 140 engineers and conducted case studies of six engineering firms from varying industries. Over 2000 engineers or engineering graduates also responded to surveys. All of this data enabled us to draw conclusions about the ways of thinking, skills, values and identities of practicing engineers. This report on problem solving is one of a series of brief reports on ideas for further enhancing the connection between engineering courses and engineering practice.

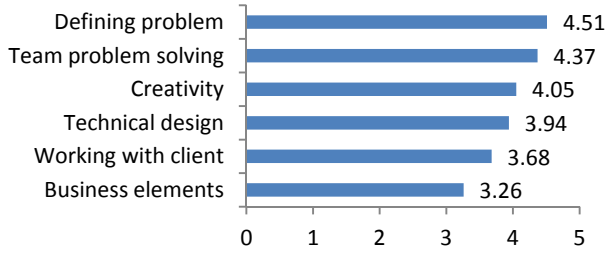
This front page details data from engineering graduates on the importance of problem solving and what it means to them. The back provides practical suggestions for incorporating these ideas in courses.

In our research we repeatedly heard engineers describe themselves as problem solvers. In one survey, when engineers ranked the top skills of "effective" engineers, a greater % of engineers ranked problem solving as the top skill than any other (see chart below).




Engineers described problem solving as much more than a technical process. For example, they noted that it is usually done as a team:

> The other nice thing about this company is . . . it's large. You don't have to look far to find other people who have been through the same thing you are going through . . . It is not just co-workers here. You can turn to the supplier . . . For this particular problem the first thing we did was we had a handful of people collecting information.
> —*Practicing Engineer*




When engineers ranked the frequency of different elements of their problem solving work, defining problems and working as a team on them came up the most frequently (see chart above, scale of 0 – never to 5 - always).

The process of solving problems also included a great deal of coordination among people and processes. Actually designing the product only made up a minor portion of the full process, as described in this quote from an engineer:

> It's not just designing of products eight hours a day. That's a couple weeks of a six month or one year project. The rest of it you are spending developing,…writing specifications, detailing the products [and] writing test plans.
> —*Practicing Engineer*

## Conclusion

Across all six of the organizations we studied and throughout the surveys and interviews, engineers continually described the complex nature of real-world problems. These problems have no clear answer and involve numerous groups of people from widely varying backgrounds. Engineers rarely acted as only a technical expert in solving these problems. They more often had to lead or help lead the effort of coordinating the different perspectives, desires, and constraints in the system. Thus, when asked what they would like to see more of in undergraduate education, they most commonly said real-world problem solving and co-op/internship experiences.

## Defining Problem Solving

What is "real-world" or "on-the-job" problem solving and how can it be connected to engineering courses?

James Trevelyan notes in "Reconstructing Engineering from Practice" that engineering problem solving harnesses the power of "distributed expertise". Courses and group projects could be designed so that students each have a piece of the overall knowledge picture that they must share.

While design is only one portion of engineering problem solving, students should still have a clear conception of the design process. Dym, et al, emphasize the use of project-based learning to teach this process.

Research by Jonassen, Strobel and Lee emphasizes that workplace engineering problems are complex and ill-structured due to multiple possible solutions, non-engineering constraints, conflicting goals, varying measures of success and unanticipated problems. For example, open-ended course projects could include constraints such as time and budget limitations as well as engineering and non-engineering measures of success.

In our conversations with practicing engineering, they constantly emphasized the importance of clear communication for solving problems, particularly as real-world problems are rarely solved individually. Refer to our reports on teamwork and communication for further connections to engineering work.

Purdue University enhances its first-year student experience by including Model Eliciting Activities – which ask students, like practicing engineers, to better understand an open-ended, client-driven problem by mathematically modeling its parameters.

## Value of Real-World Activities

Course activities that connect to real-world design and problem solving from day one in engineering have been shown to increase retention and engagement of engineering students.

> "The most valuable part of my undergraduate education was actually the … club … The hands-on work I did there taught me more than any class I took."
>
> -- Engineering Alumnus

## Assessment

Student portfolios of work – Portfolios and presentations of these portfolios allow faculty to assess student work and problem solving abilities in a more authentic way than traditional presentations of writing tasks.

View this poster by Docktor and Heller for ideas on using a rubric to assess students' problem solving steps in a technical course.

To get at improving technical problem solving within courses, the Stanford Center for Teaching and Learning suggests, **"**Rather than simply requiring students to do a number of problems for homework, the instructor asks students to solve a problem and also to write down step-by-step what they were thinking at each stage of the problem-solving process. Reading through these solutions gives an instructor a sense of how well the students are developing their problem-solving skills and can help the instructor determine how much class or section time should focus on improving this academic skill."

## Links to Related Articles

"Engineering Students' Mathematical Problem Solving Strategies," by Cardella & Atman

"Design or problem solving," by Holt, Radcliffe & Schoorl

"Learning to Think Mathematically: Problem Solving, Metacognition and Sense-making in Mathematics," by Schoenfeld

Case-studies provide one method of connecting to real-world problems and allowing students to transfer knowledge to new arenas, by Jensen.

## Link to Online Version

Link to our project for online resources and live links

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