the psychology of INSIGHT

ENGINEERING IS A MATTER OF THE CONCRETE AS WELL AS OF THE ABSTRACT. BRINGING THE TWO TOGETHER CAN YIELD SURPRISING RESULTS.

BY SUSAN STAFFIN METZ

Anyone who has ever attended an engineering school, either as a student or a teacher, knows that the number of students who graduate is smaller—often much smaller—than the number who enter the program.

In fact, between 30 and 60 percent of students who initially enter engineering switch majors, according to a survey by the Project to Assess Climate in Engineering which looked at 10,000 students at 22 engineering schools. Dropout rates are highest during the first two years.

It is a loss because many students who drop out of engineering programs are academically prepared. Most received high scores on standardized math tests and did well in high school and in advanced placement science classes.

There is no reason they should not become engineers. Engineering schools can do a better job—a much better job—of making sure that happens.

Researchers have accumulated decades' worth of studies on time-effective, low-cost actions that engineering faculty can take to improve student retention rates. They include using everyday examples to teach engineering concepts, improving spatial visualization skills, and changing how faculty interacts with students.

Individual faculty or entire engineering schools can implement these strategies without expending much time or money. They do not require any significant changes in curricula or course design, yet they can make dramatic differences in outcomes.

While these strategies work for all students, they have a disproportionately positive impact on women and under-represented minorities. For example, Michigan Technological University, found that 80 percent of the women who took spatial visualization training classes graduated in engineering, compared with only 50 percent of those who did not. That is a significant, even remarkable, difference.

The National Science Foundation funded the ENGAGE program in 2009 to make this research available to engineering faculty. The program currently works with more than 50 engineering schools. Modeled after cooperative extension services at land grant institutions, ENGAGE identifies evidence-based retention strategies and develops ways to use them in the classroom. It recognizes that professors are pressed for time, so it develops turnkey tools and resources that implement retention strategies without spending time on course development.

1. everyday examples

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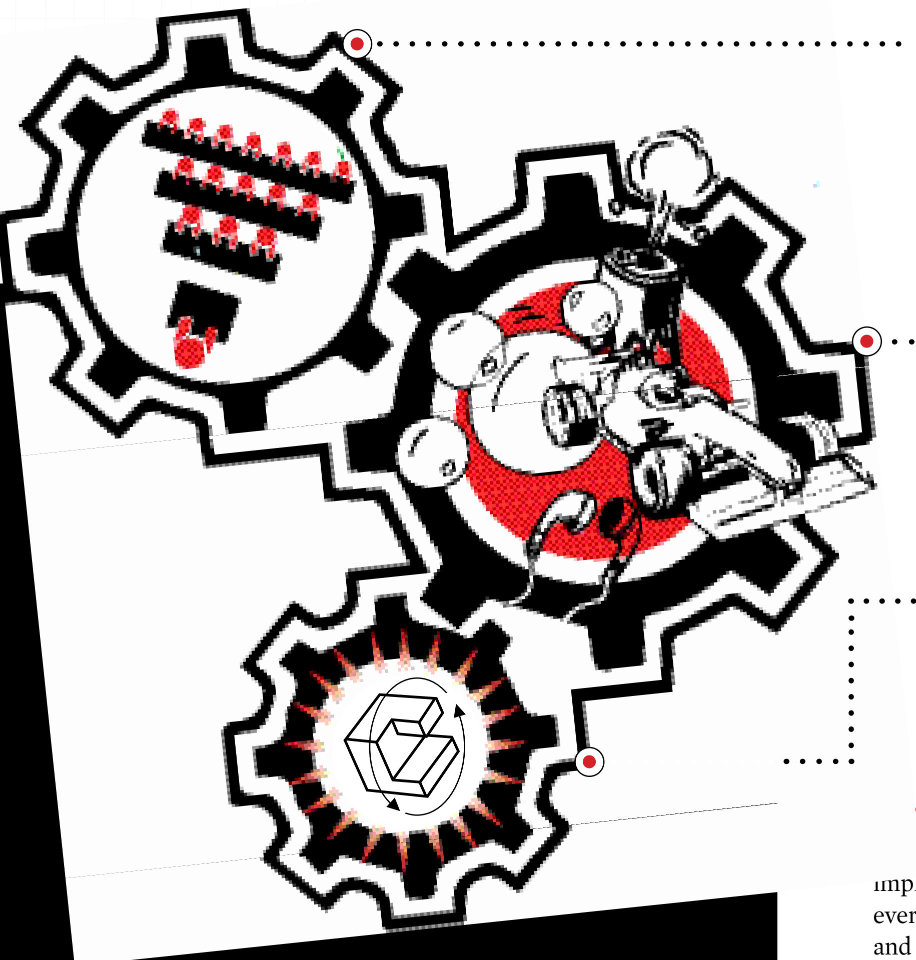

IMPROVE how faculty and students interact inside and outside of the classroom.

INTEGRATE everyday examples in engineering into courses

IDENTIFY and remediate students with weak spatial visualization skills

Why is it better to teach theory from earbuds, soap bubbles, exploding soda cans, racecars, and Silly Putty? Using relevant everyday examples to explain engineering concepts is a powerful way to make engineering knowledge more practical.

ERYDAY EXAMPLES

AGE focuses on three evidence-based, easily implemented strategies to improve retention: Integrate everyday examples in engineering into courses; identify and remediate students with weak spatial visualization skills; improve how faculty and students interact inside and outside of the classroom.

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An example of someone who does this is Scott Kiefer, an assistant professor of mechanical engineering at York College of Pennsylvania. He teaches a class on the mechanics of deformable solids. In the past, he used two concentric metal tubes to explain basic axial stress and deformation, and how these concepts could be used to solve statistically indeterminate problems.

Then, one day, he walked into class with his iPod earbuds plugged into his ears. He used the iPod headphone wire to explain the same principles. While the calculations for the earbuds and concentric tubes were the same, students paid more attention to the iPod example. In fact, several had broken their earbuds and wanted to know why that had happened.

After the lecture and before his first exam, Kiefer asked students what he could change about his lecture. Roughly 25 percent suggested adding more examples like the iPod.

"I thought this kind of example would be fun, but it was more than that," he later said.

So why are everyday examples so important? Why is it better to teach theory from earbuds, soap bubbles, exploding soda cans, racecars, and Silly Putty, rather than generic I-beams, fluids, and materials?

First, most students already know something about these examples. They may have shaken up a can of soda, pulled Silly Putty until it broke, or touched a soap bubble and watched it pop. This gives them an intuitive understanding for how these objects behave. It improves their ability to visualize how various forces might affect these objects.

Second, studies show that students are easier to engage when they start with things they already know. They are more likely to remain interested in the topic and retain what they learn.

Third, ASME recently surveyed 1,400 engineering supervisors. More than half of them believed their entry level mechanical engineers lacked practical experience in how devices are made or work. Using relevant everyday examples to explain engineering concepts is a powerful way to make engineering knowledge more practical.

Finally, students find instructors who use everyday examples in class seem more approachable. When professors pepper lessons with everyday examples, students are more likely to ask questions and to rate their instructors higher in course evaluations.

VISUALIZING SUCCESS

Well developed spatial skills play a critical role in engineering. A rigorous body of research supports the concept that strong visualization skills leads to persistence and success. This is true not only in engineering, but in mathematics, computer science, chemistry, and architecture. In fact, the National Science Board maintains that spatial skills are as necessary for engineering success as math and verbal skills.

Not everyone enters engineering school with outstanding visualization skills. Fortunately, these skills are malleable. Students can improve their performance dramatically without a significant time commitment. Thanks to decades of research by Sheryl Sorby, professor emerita of mechanical engineering at Michigan Tech and currently a visiting professor at Ohio State's Engineering Education and Innovation Center, we know how to remediate low visualization skills.

Since graphics is now part of most first year programs, helping students develop 3-D spatial skills early is important. A 1985 study found that of 11 variables, the best predictor of success in that class was a student's score on the Purdue Spatial Visualization Test: Rotations (PSVT:R). It measures students' ability to visualize how a complex shape will look when flipped or rotated into a different position.

Sorby's team at Michigan State has been giving the PSVT:R test to incoming engineering students since 1993. At first, she encouraged students who scored lower than 60 percent to enroll in a voluntary 10- to 14-hour visualization class. Students who completed the course improved their score on rotations by 50 percent.

More importantly, though, their enhanced visualization skills led to better academic performance. Not only did they earn better grades than students who failed the rotations test, but they also surpassed students who had received low (60-70 percent) passing grades on the test.

All students who do poorly on spatial visualization tests would benefit from remedial instruction. Women and students from lower socioeconomic groups, however, tend to underperform on these tests. They gain the most from skills training. In fact, it was Sorby who found that 80 percent of the women who took the spatial skills class re-

2. visualization skills

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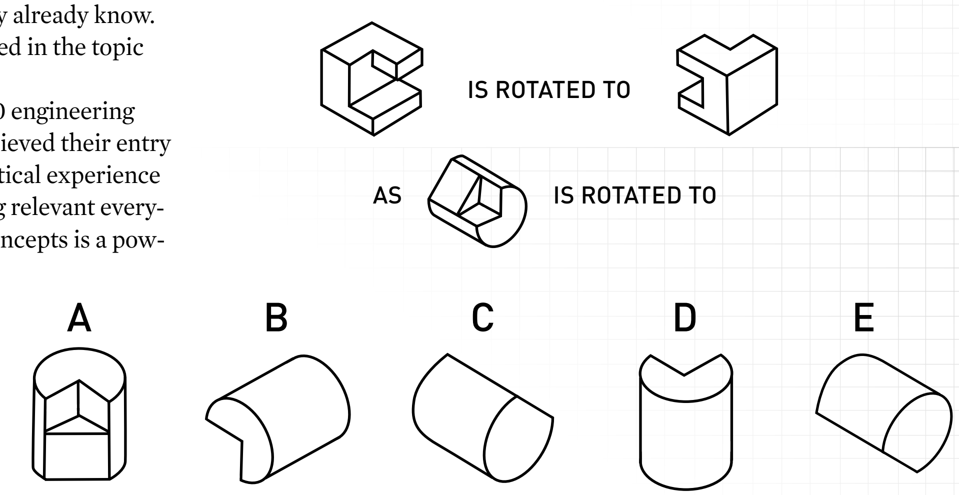

The Purdue Spatial Visualization Test: Rotations (PSVT:R) measures students' ability to visualize how a complex shape will look when flipped or rotated into a different position. According to a study, the best predictor of a student's success in engineering graphics was his or her score on the test.

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mained in engineering, compared with only 50 percent with weak skills who did not take the class.

"These women were more confident as they progressed through the engineering program because as they persisted, they had a better understanding of the concepts that were being presented," Sorby explained.

"Engineering professors tend to communicate by drawing pictures. If you don't understand the pictures, you're not going to understand what the professor is talking about.

"What we found is that helping these students improve their spatial skills improved their success rate in engineering. It didn't necessarily improve all their grades, but it improved their willingness to stick it out and become engineers," she said.

HELLO, I'M YOUR TEACHER

How important is faculty engagement with students?

According to Norman Fortenberry, executive director of the American Society for Engineering Education, the two most important predictors of student engagement, retention, and performance are faculty discussions with students about engineering work and positive faculty feedback about students' ability to do the work.

A clear link exists between faculty engagement and student satisfaction, degree completion, and even engineering employment after 10 years.

Faculty engagement can mean many things. It encompasses a continuum that ranges from words of encouragement to more time-consuming, face-to-face mentoring. ENGAGE promotes interactions high on impact and low on faculty time commitment.

One example is "Hellos in the Hallway." This strategy is one of the easiest tips to implement. A professor who taught in different classrooms adopted it. She often walked between rooms with her head down, looking at notes and going over her next lecture. After participating in an ENGAGE webinar, she changed her behavior and began to smile and say hello to students when walking to her next class. This modest behavioral alteration seemed to make her more approachable, the professor reported. As a result, more students asked questions in class and stopped by during office hours.

As part of an ENGAGE mini-grant, University of Texas at Austin encouraged faculty to participate in a "connections class." This is a 20-minute segment of one class where instructors talk informally to students about their research, industry experience, family, hobbies, or career advice.

After an initial pilot, Texas launched 43 classes involving 2,300 students. Of 300 students who responded to an on-line survey, 94 percent indicated that they valued the classes. One student volunteered that the experience made the professor more approachable and less intimidating to meet during office hours. A second student was motivated by an instructor's passion for his research. A third summed it up, "Freaking awesome."

That is important because faculty have an enormous impact on student behavior. While the most casual negative remark can send a student into a tailspin, encouraging words are powerful and can motivate him or her to work harder.

GOING FORWARD

Students do not drop out of engineering at higher rates than other majors. Yet engineering schools face high attrition. This is because their rigorous, lock-step course requirements make it difficult for students to switch into engineering programs as easily as they do into other majors without increasing their time to degree significantly. Engineering schools need to work harder than other disciplines to retain their students.

Using everyday examples, improving spatial visualization skills, and developing better faculty-student interaction fit into existing engineering programs without curriculum reform. ENGAGE's website (www.EngageEngineering.org) includes the research supporting each strategy.

More important is that the website provides resources including webinars, videos, downloadable lesson plans, e-newsletters, and turnkey presentations that enable schools to implement these strategies without investing time and resources in course development.

Faculty and staff can easily access these materials with no cost or membership requirement. Adopting these strategies school-wide requires the leadership of department chairs and deans.

ENGAGE is currently working with more than 50 engineering schools, and plans to expand to more than 65 schools this year. Those schools are committed to improving the undergraduate experience for their students.

ENGAGE strategies support their efforts and facilitate student success. ME

SUSAN STAFFIN METZ is the principal investigator of ENGAGE and the director of Diversity and Inclusion for Stevens Institute of Technology in Hoboken, N.J. The co-principal investigators of ENGAGE are **C. Diane Matt**, executive director of the Women in Engineering Proactive Network (WEPAN), and **Patricia Campbell**, president of Campbell-Kibler Associates. The work is funded by the National Science Foundation (Grant No. 0833076).

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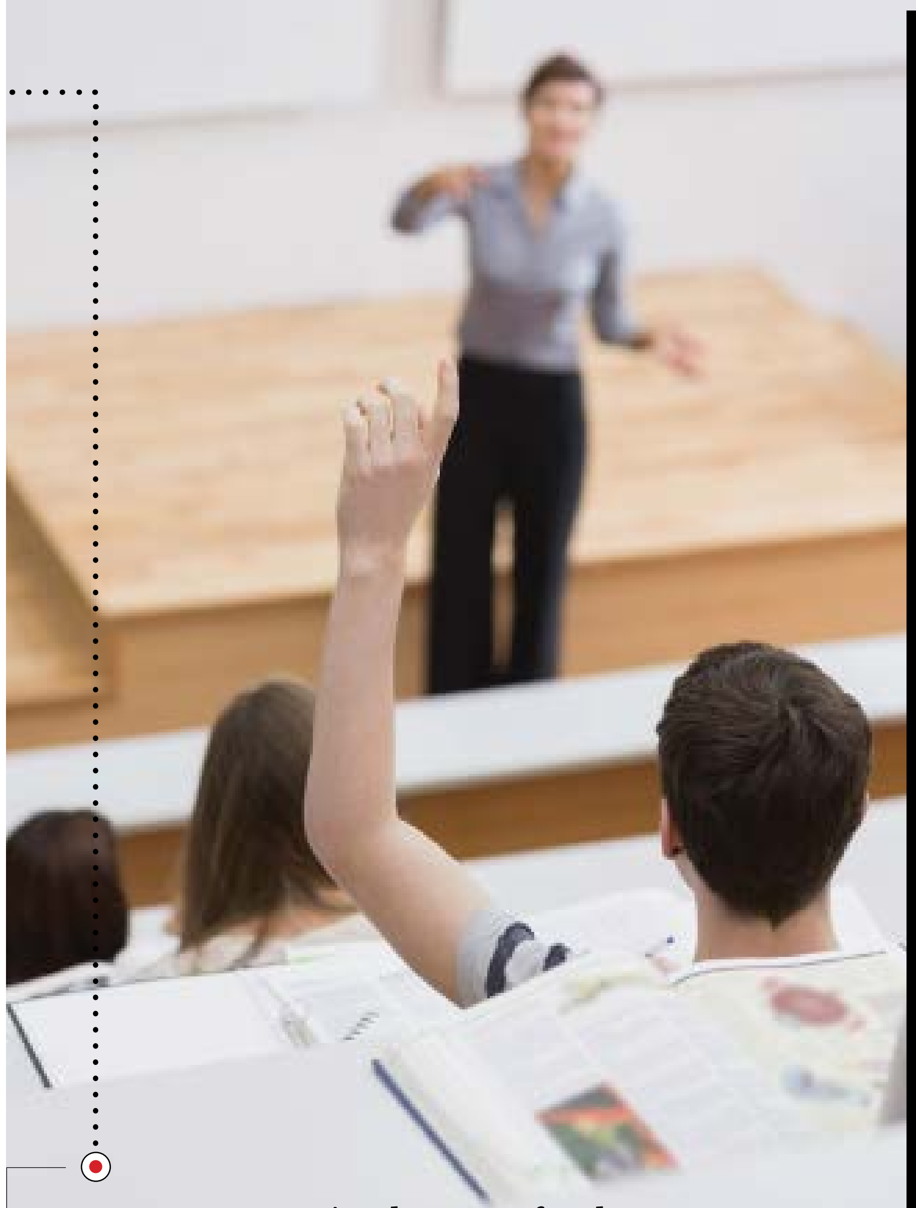

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ENGAGE
The "Strategies" section of ENGAGE's website has links to research, lesson plans, solutions, and other resources: **EngageEngineering.org.**

WOMEN IN ENGINEERING PROACTIVE NETWORK
The WEPAN Knowledge Center is an online resource for research and best practices in retaining and advancing women in engineering:
www.wepanknowledgecenter.org

ENGAGE IN ENGINEERING
A YouTube channel that includes short demonstrations of everyday engineering examples: **www.youtube.com/user/engageengineering.**

PACE
The Project to Assess Climate in Engineering is a researches issues that affect retention of students in undergraduate engineering programs. PACE is headquartered at the Center for Workforce Development at the University of Washington:
depts.washington.edu/paceteam

"REDUCTION TO PRACTICE"
ASME's Vision 2030 task force seeks to narrow the gap between engineering schools and industry: November 2012.