GRABCAD

Modernize Your Engineering Curriculum

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Introduction

A good engineer wants to be modern.

To be modern is to be current, and that, more than anything else is what engineers should be. And this is what engineering professors are, and should, be thinking about. Engineers have wrestled with how to stay current for at least 15 years, even though professors and academia are trying their hardest to move the ball along.

Don't believe us?

Here's a link to a study published way back in 1999, highlighting how an engineering professor struggles with matching the pace of her curriculum with not only the pace of technological advancement, but with the resulting demand in the workplace. Fourteen years later, researchers were ***still citing*** nearly the same issue, lamenting the "disconnect between the system of engineering education and the practice of engineering."

"How to prepare engineering students for the world that awaits them" is a theme that doesn't seem to be going anywhere—at least not quickly. Engineering educators face the challenge of fitting a whole lot of curriculum into one program. At the very least, students need to graduate having mastered the technical fundamentals and gained some

proficiency with any number of modern engineering software packages. Most professors need to also put engineering as a discipline into perspective. As a result, curriculums over the past few years have incorporated global, societal, economic, and environmental (GSEE) issues into lectures in labs. And if there were time after that, it would be nice to teach about modern manufacturing techniques (like additive manufacturing) and combinations of disciplines (like mechatronics) that will define the contours of engineering for years to come.

The idea that engineering is simply calculus plus a list of topics pulled out of the ***Grinter Report*** is clearly an outdated one. Today's curriculum should include:

- Technical fundamentals
- Software and cloud tools (including but not limited to CAD)
- Modern manufacturing techniques
- GSEE frameworks
- Lessons on how to integrate subsystems from mechanics, electronics, chemistry, biology and informatics to an optimal total system of high technology
- Lessons on how to analyze, simulate, and control multi-scale interdependencies
- Downstream curriculum (mechanical design, product development, entrepreneurship or production management)
- Mechanics of solids (statics, dynamics and strength of materials)
- Fluid mechanics
- Thermodynamics transfer and rate mechanisms (heat, mass, and momentum transfer)
- Electrical theory (fields, circuits and electronics)
- Nature and properties of materials (relating particle and aggregate structure to properties)
- Intellectual property and ethics
- Communication, negotiation, project management, and other soft skills

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So, What Are You Getting Yourself Into?

This eBook is aimed at the engineering professor, new or experienced, that is interested in how their peers are thinking about the challenges associated with modernizing their curriculum. Be forewarned, this is not a guide to get your department's curriculum overhauled. It is also not going to give you the answer on how to set the vocation on its proper course to modernization, right now. Academe being what it is, that process can take years and is fraught with sets of challenges all their own. But there are people out there looking at the evolution of engineering curriculum in particularly innovative ways.

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What Do You Mean By Curriculum?

Before we can talk about modernizing engineering curriculum, we first have to agree on what we mean by "curriculum." It's here where one might scoff and instruct the author to simply pick up a dictionary. And that's not necessarily bad advice or a bad place to start, to be really honest.

Curriculum

A set of courses constituting an area of specialization.

Great. That's what you thought it meant all along and the last thirty seconds have been a total waste of your time, right?

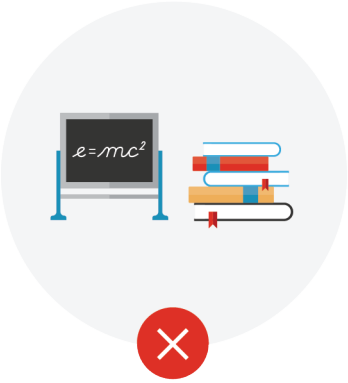
Not quite. "Curriculum" belongs to an unfortunate group of words that have been burdened by implication and associated mechanisms. It's not enough to simply describe a list of courses that make up a university's engineering program.

Instead, "curriculum" is used to describe not just the courses, but the content, the program structure (how many credits each course is worth), and sometimes, the teaching or learning method.

This is extremely burdensome because it's at this point that administration gets involved (or worse, department chairs and deans). It also happens to be, objectively, excruciatingly dull. We're interested in the content itself, not how many credits it's worth. And while learning theory is objectively not at all dull, it's a bit outside of this eBook's scope.

So, to recap, what are we talking about when we say "curriculum?"

We're talking primarily about the content of the courses. Sometimes we'll mention the courses themselves just to give the content a vessel. Also it'd be more than a little confusing (not to mention imprecise) to avoid mentioning that a certain topic or exercise is meant to take place in a lab instead of a lecture.



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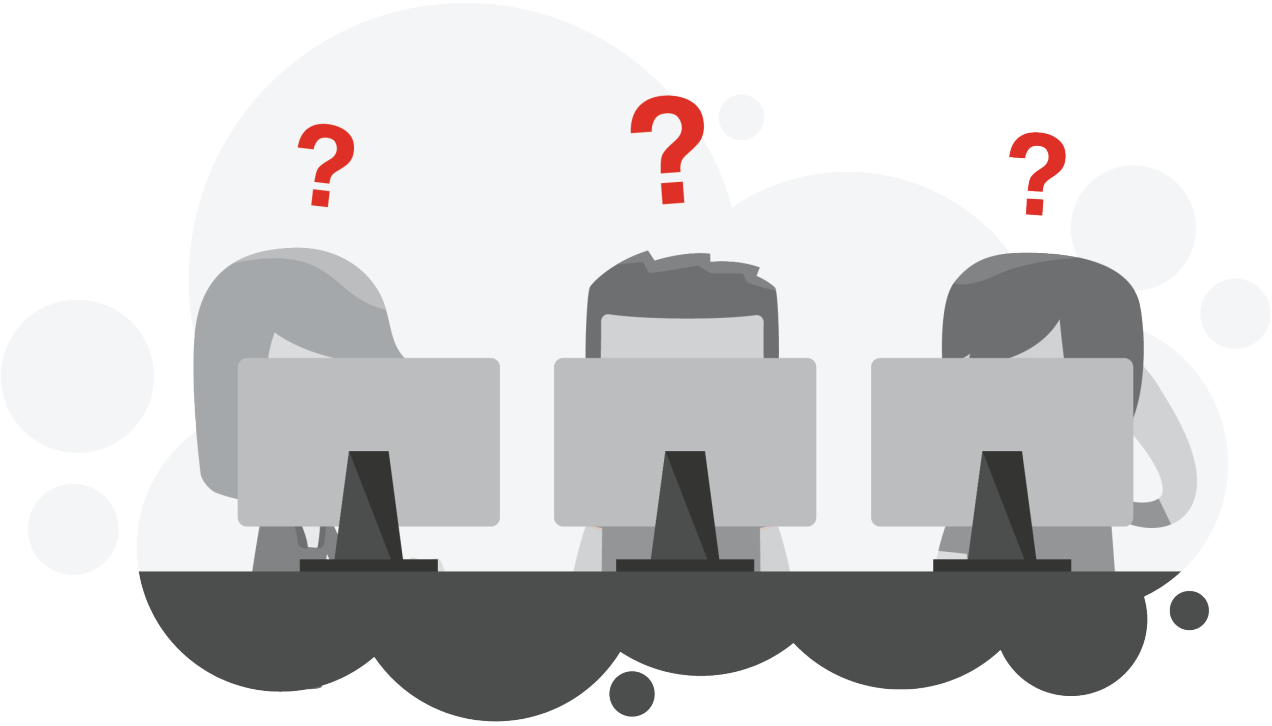
Why Should You Modernize?

Most engineering professors understand the broad strokes of why it's important to present a modern curriculum to students. Cursory research reveals two "distinct currents that are driving ME programs to reform their curricula."

The emergence of new technologies that are revolutionizing the practice of engineering.

New technologies? What new technologies? Let's consider this list (by no means exhaustive) of increasingly important (and unfortunately not as increasingly included in engineering curriculum) courses identified by Delale et al:

"The miniaturization of mechanical devices, the advent of nanotechnology, the advances in information technologies, the emergence of intelligent systems, the introduction of new and advanced materials, the development of sophisticated software and finally the revolution in biology cannot be ignored in designing a modern mechanical engineering curriculum."



Despite leaving advanced manufacturing techniques (like additive) conspicuously off the list, Delale et al pretty much nail it. Of particular interest is the attention paid to the development of sophisticated software. Even if you remove CAD systems from the equation—a considerable proposition—there exists a wide array of software in which students receive virtually no formal training prior to their first job.

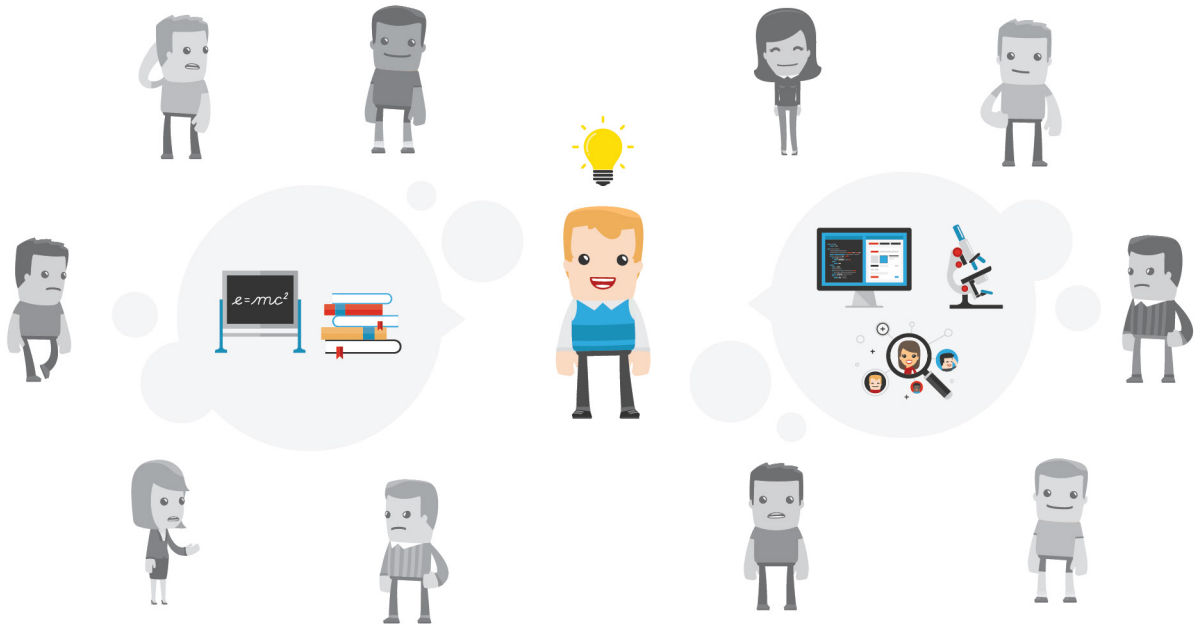
How did Delale and his colleagues come to the conclusion that students don't receive enough software training? They saw it in their own classrooms:

> "One indication of this problem was that students in senior design courses were often uncomfortable with design projects sponsored by our research laboratories or by industry when they departed from the traditional mechanical engineering knowledge base and involved emerging technologies."

A new trend in pedagogy that is gaining currency among science and engineering educators.

According to this reform movement, engineering education must take into consideration industry needs, must be based on cognitive science, and should promote technological literacy.

It's tough not to sense a pattern here. A modern curriculum prepares students for modern jobs – not the jobs of a decade ago. Technological literacy goes hand in hand with today's jobs. Every student that comes out of school knowing how to use the same software and equipment that the industry uses is one less engineer the industry has to spend time training.



Better still if that student is familiar with technology that is more advanced than the industry standard. Innovation isn't necessarily a bad thing. It's important to note that no one is arguing against teaching the fundamentals. The argument is for teaching a set of modern skills on top of the fundamentals. After all, an engineer who doesn't know the basics isn't of much use to anyone. And they certainly aren't capable of mastering more advanced concepts and practices that are in demand.

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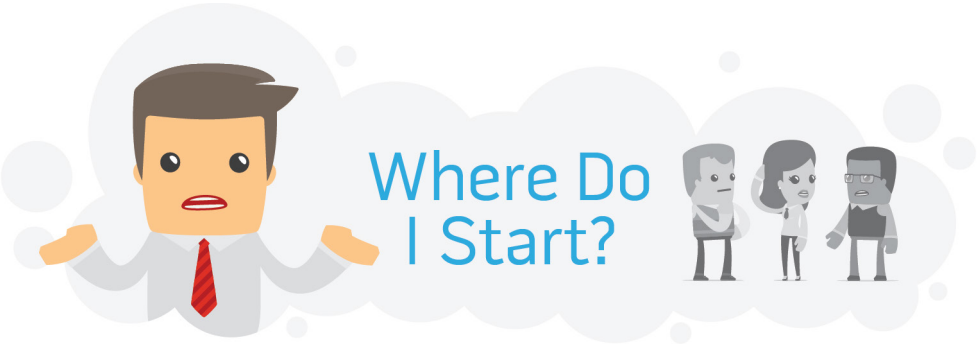
What Should You Modernize?

Ok, great. You either started reading this eBook already comfortable in the knowledge that your curriculum needed modernizing or, somehow, we convinced you that the twenty-year push to modernize is real. But there's an obvious question that hasn't yet been addressed.



The answer is going to vary dramatically from program to program and university to university. That sounds like a cop out, but it's the truth. We wouldn't try to presume that we understand the nuances of every engineering program on planet earth.

With that said, we can discuss examples of courses where engineering professors have tried to modernize, either by incorporating challenges that cut across the curriculum or by focusing on new technology. Most examples fall into two categories—design and lab.

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Design

"Engineering design is known as an answer to an ill-defined problem. As any answer to an ill-defined problem, it can never be completely right or completely wrong. The methods that universities use to teach engineering design, as a consequence of this, suffer from the same fate." —Silva, et al.

Doesn't exactly give you the warm and fuzzies, does it?

Silva and his coauthors go on to point out a familiar theme—fresh engineering graduates struggle with problems "where the boundaries aren't well defined, are interdisciplinary, require the use of effective communication, and integrate non-technical issues.

"These skills are largely absent from traditional engineering curricula."

Let's take his concerns one at a time:

Poorly defined boundaries

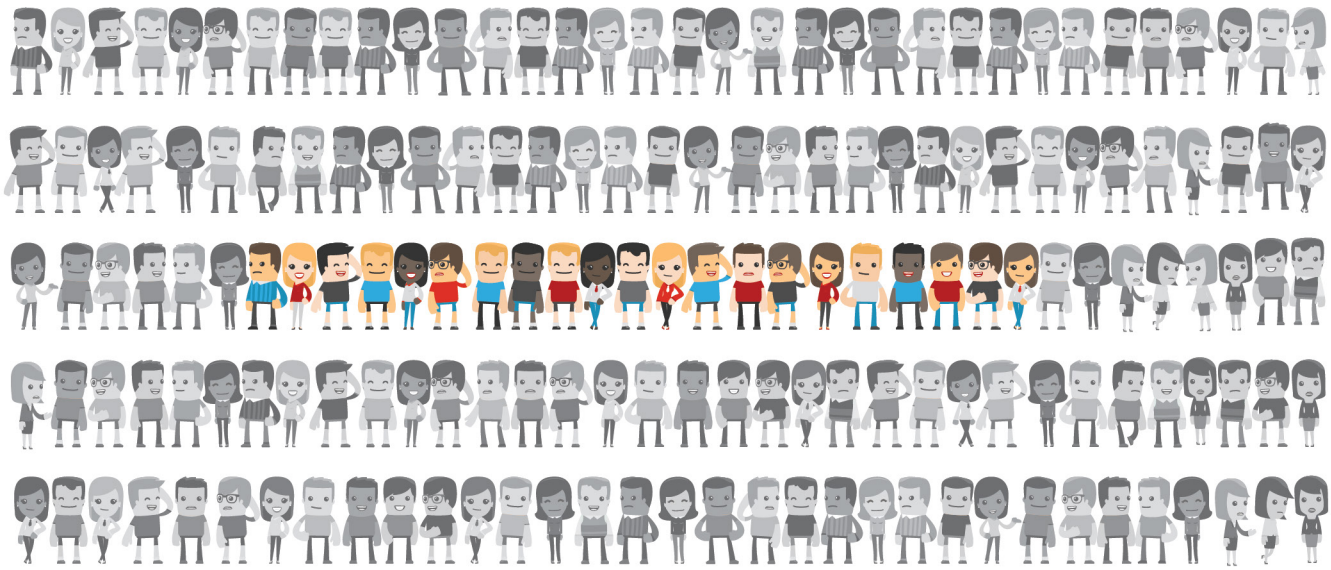
To be fair, a great number of people (engineers and otherwise) struggle to execute in an environment with poorly defined boundaries. Poorly defined boundaries can be indicative of poorly designed goals, communication processes, and ineffective leadership.

The obvious solution to circumstances where there isn't much clarity is to provide clarity. If the boundaries cannot be stated any more clearly, it falls on leadership to indicate as much. Leadership must also be prepared to deal with efforts that stray from the core problem. After all, it is not possible to identify boundary markers without first engaging in a little exploration. This is something that can be highlighted in a university setting, but it's really up to "real-world" managers to put this into practice.

Interdisciplinary problems

As interdisciplinary challenges grow and, indeed, produce inherently interdisciplinary fields (like the aforementioned mechatronics), the demand for students that are comfortable with a variety of formerly compartmentalized skills will rise accordingly.

Make no mistake. This is a giant topic to which a considerable amount of university research is directed. Breaking down the barriers between longstanding engineering disciplines, especially in academe, requires persistence and commitment to finding a solution (even if that means 20 students out of 200 will participate in an experimental curriculum).



That's exactly what professors at the Instituto Superior Tecnico in Lisbon researched and published this year. Citing the growing need to conquer "design problems that are growing in complexity and cut across several traditional knowledge boundaries [that] require broad collaboration skills replying on more than the traditional 'divide and conquer' approach," the professors at IST set up a project that spanned multiple courses.

In their words:

"A project that cuts across several courses was set up, in which the students work on the same project but tackling different problems during each of the courses. In the TD&GM course, the students were asked to design small appliances during the semester. In the end, they had to present their design project, but also show a working prototype of the product."

(It's worth checking out the ***entire study*** – it can't be done proper justice here.)

In sum, interdisciplinary challenges can be solved by improving transparency and communication while working on the same project over a number of courses that view the project from a different discipline.

Effective communication

In the paragraph above, the course plan was laid out very clearly. What was not laid out very explicitly was how, exactly, to enable increased transparency and communication. What kind of software tools out there support such an endeavor?

Enter GrabCAD Workbench.

Workbench is a purpose-built tool that allows students to store designs in the cloud, track versions, and manage a host of other useful things. Workbench allows for professors to track student progress and make annotations where necessary. And by the way, it's totally free.

In a situation where students are working on the same problem across many courses, it's difficult to imagine a better solution. Even if one were to limit the discussion to strictly the senior capstone, Workbench is still enormously powerful.

"Communication is a major concern for engineers, as it is perceived as [a] recurring problem in their careers. By teaching design and communication in the same course for freshman at the Northwestern University, Hirsch et al found a way of dealing effectively with this issue and at the same time enhance the students' ability to tackle future engineering courses and career." —Silva, et al.

Integration of non-technical issues

We already mentioned the GSEE paradigm and how important it is to a modern curriculum. GSEE was introduced by Outcome h, perhaps the most critical in a series of desirable outcomes described by the Accreditation Board for Engineering and Technology (ABET) since 1996.

Outcome h ***can be described*** as "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."

The problem that almost always arises when considering Outcome h is measurement. How do you measure the success of a "broad education" that addresses four very complex and sometimes abstract ideas? Some researchers believe that even if measurement weren't an issue, "most departments do not have the flexibility or the room to develop a new course specifically to address any single ABET outcome, much less Outcome h. As a result, most departments relegate this requirement to their senior capstone design experience along with many other ABET outcomes. The end result is a course that does too little while trying to do too much."

Product archaeology

If you are in a position to create a course that addresses ABET outcomes, especially Outcome h, what might it look like? Most research points to product archaeology – defined as "the process of reconstructing the lifecycle of a product – the customer requirements, design specifications, and manufacturing processes used to produce it – to understand the decisions that led to its development."

Why product archaeology? Russo et al suggest that "archaeology is at the intersection of science and humanity; like engineering, it uses practical observations and scientific experimentation to observe, experiment, and draw conclusions." If archaeology is a fair engineering analogue, then it does seem reasonable to borrow pedagogical frameworks. This is especially true when one considers that archaeology has long been at the intersection of science and humanity, whereas engineering only recently finds itself in the same position.

Essentially, the goal is to include courses at both the lower and upper level that "that develop students' understanding of the broader context of engineering. In doing so, PA has been found to serve as a scalable and sustainable pedagogical foundation for engineering that provides a platform to enrich the limited exposure that students currently receive to GSEE-related issues." More details can be found on the product archaeology site.

Art

If one were to require further evidence that the modern curriculum requires an emphasis on engineer's broader context, one could look to the College of Engineering at the University of Iowa. Engineering students at UI will be required to take at least one art course taught by the College of Liberal Arts and Science. The courses available to engineers will be specifically tailored to them.

"We see this requirement as really enhancing the education our engineers get and preparing them for the 21st century by helping them understand the broader societal context in which engineering is based," said Alec Scranton, dean of the UI College of Engineering.

> "We are trying to graduate a broad engineer."

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Conclusion

Creating a "broad engineer" is, of course, so much easier said than done. The curriculum creates a broad engineer is more than just familiarizing students with concurrent engineering. Instead (or in addition, depending on your perspective), the modern curriculum borders on the interdisciplinary. It must draw from nearly every practice area at nearly every stage.

There's a reason the literature has been calling for curriculum modernization for almost twenty years. It's hard. Really hard.

But it's not impossible. In this eBook we identified specific areas to apply incremental modernization along with context for broader curricula reform.

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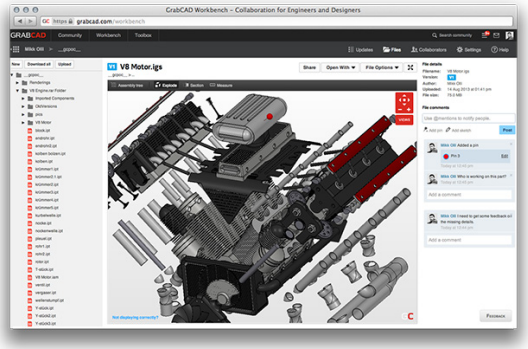
Suggested Content

Makerbot Education

Stratasys Education

Try Workbench



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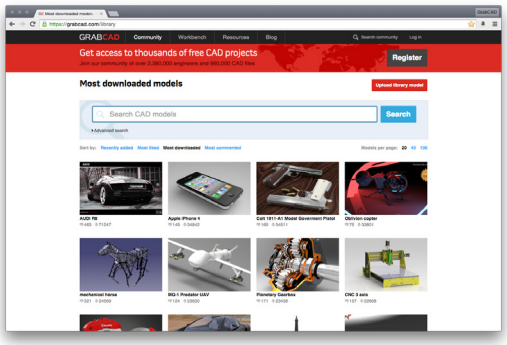

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