IDALIS VILLANUEVA ALARCÓN

How to Build Engineers for Life

When I was six or seven years old, an elementary teacher asked me to write down what I wanted to be when I grew up. I listed three options: doctor, teacher, and engineer. My teacher was surprised I knew that last term. I'm still not sure where I learned the word but I learned the spirit of engineering from my father.

Although he hadn't finished high school, my father singlehandedly constructed one of the first analog satellite dishes in Puerto Rico, giving us the gift of satellite broadcasting channels from around the world. He let me help make measurements, lay out designs, and figure out how pieces of the dish fit together—a practical puzzle I could solve. I loved how we could build something useful from stuff we had at home, a few things we found at junk yards, and the odd purchase from RadioShack. When my dad had a thought for something new, he'd take the time to read everything he could find about it. He wasn't afraid to build something from his ideas. Later, when I entered college, I had that format to draw on. You don't get stuck on a problem; you go learn more. Without that example, I doubt I would have become an engineer.

As I continued my education, I began adding the word "engineer" to other potential career options: medical engineer, mechanical engineer, psychological engineer. From certain angles, my jobs look like they've come from separate career paths. After my PhD in chemical and biological engineering, I worked in cell biology and taught bioengineering in Maryland. Then I went to Utah State University to research how diverse people self-advocate within engineering training programs and what keeps them from doing so (work for which I was honored with the Presidential Early Career Award for Scientists and Engineers).

As a Latina first-generation college graduate, I had to learn to navigate this path through my own education and career advancement. Now I apply that knowledge to my current work at the University of Florida, where I teach engineering, research engineering education as an associate professor, and serve as associate chair of research and graduate studies. Cumulatively, my work and life have taught me the importance of lifelong learning—as well as why engineering education, mired in its rigid university-based training programs, is neither serving that need nor grappling effectively with what keeps it stuck.

Lifelong lacking

Lifelong learning refers to an ability and willingness to keep improving and evolving within and outside formal schooling. It is essential for maintaining a competitive workforce, but engineers are not doing nearly enough of it. One analysis attributed the so-called shortage of science, technology, engineering, and mathematics professionals to graduates' inability to keep up with technical change, finding that earnings stall over time as older workers' skills grow obsolete. The National Academy of Engineering issued a report on the issue as early as 1996. It noted that a decade prior, experts estimated that half of everything a mechanical engineer knew about their field would be obsolete in seven and a half years; for software engineers, it was two and a half years. Similar concerns were raised in the academy's 2012 report, *Lifelong Learning Imperative in Engineering*. Not long after, an ongoing National Science Foundation (NSF) initiative called Revolutionizing Engineering Departments began offering grants to overhaul engineering curricula to be less rigid and more relevant to modern society's needs.

Despite escalating calls for lifelong learning, most engineering departments are still set up to funnel people into ever-more-specialized silos, creating cul-de-sacs instead of the intersections and roundabouts necessary for engineers to stay ready to solve problems in the real world.

One reason change is slow is that barriers to lifelong learning are more than simple inadequacies within any curriculum. Instead, barriers are integrated into engineering culture and coursework and grounded in assumptions about how engineering education is supposed to work, who is supposed to take part, and how engineers should behave.

These assumptions are referred to as the "hidden curriculum," a term introduced in the scholarly literature in the 1960s. A hidden curriculum contains largely unarticulated cues about how people should engage with school, learning, and work. Consider the hidden curriculum in engineering conveyed in phrases like "weeder courses," or classes designed to systemically make passing them incredibly difficult. Engineering coursework is treated as an assembly line to turn students into engineers (and remove "defective products" along the way). Problem sets have fixed correct answers based primarily on technical specifications; cultural relevancy and societal impacts are considered superficial window dressing, not worthy topics, or opportunities for further learning.

This hidden curriculum teaches that successful engineers proceed lockstep through traditional four-year college degrees, blinkered away from extraneous nonengineering topics. Individual achievements and academic prestige are prioritized over community. Technical solutions, as defined in an assignment, eclipse the ability to explore and integrate.

Embedded in engineering's hidden curriculum is an emphasis on a mindset of "schooling" as opposed to learning (let alone lifelong learning). The schooling mindset values rote memorization over applied knowledge, grade point average over competency, grading curves over mastery, plug-and-chug equations over conceptual mapping and understanding, and individualized problem-solving over truly collaborative idea generation and formation. Each of these schooling priorities subverts outlooks that are essential for lifelong learning. To support lifelong learning, engineering educators need to develop a more nuanced understanding of the discipline's counter-effective hidden curriculum and design strategies to counter it.

Silos stifle passion

Harms of the hidden curriculum extend to attitude as much as knowledge and training. To find solutions, an engineer should first seek ideas from divergent sources in the world around them. The productive dance of divergent and convergent sifting requires appreciation, openness, and a certain amount of passionate interest, fueled by both curiosity and pursuit of societal good. Without this passion, there is less impetus to reach into different engineering realms. Passionate interest can be achieved via an instructional approach known as "heutagogy," or self-determined learning. That in turn demands the space, time, and flexibility to straddle different disciplinary approaches.

But, within engineering departments, passionate interest is all too often subverted as degree programs pile on prerequisites and requisites and channel students into specialties with little scope to select courses of personal interest. Someone who enters a mechanical engineering program has limited options to also study policy, for example. As philosopher of engineering Carl Mitcham wrote in this journal, "Engineering programs, because of their rigorous technical requirements, tend to be the worst offenders at cutting intellectual exploration short."

With course designs that have barely changed since the 1950s, engineering's hidden curriculum is one of permanent silos. And as an engineer becomes ever more specialized, their expertise is expected to become a thin, isolated pyramid of knowledge, eschewing the broad interdisciplinarity that is needed for problem-solving. But why should interests narrow with advancement?

Several US engineering programs are attempting to broaden these narrow expectations. My undergraduate engineering program was highly unusual for requiring majors to have a humanities minor; it was understood that without a broader educational background it was impossible to be a "whole engineer." NSF's Revolutionizing Engineering Department programs include the Integrated Engineering Department at the University of San Diego, which is explicitly designed to provide a background in liberal arts and prepare students for a range of engineering professions. The Iron Range Engineering program, affiliated with the Bell Engineering Program at Minnesota State University, Mankato and its community college partners, offers faculty-coached two-year internships and cooperative education programs (or co-ops) anywhere in the world. Instead of rigid, specialized engineering tracks, Wake Forest University offers a program in which students can tailor 40% of the curriculum to their interests. Colorado School of Mines and Oregon State University both offer humanitarian engineering programs, which include service learning and courses on topics like environmental and social sustainability.

But even this encouraging list reflects another aspect of the hidden curriculum: recognizing formalized education without regard for other "funds of knowledge" brought in from outside the classroom. Learners' experience in sewing, carpentry, poetry, or skills passed down through generations can often help them connect the dots and become better engineers. I am not alone in finding that hobbies and passions (in my case, art and theater) have deepened my engineering work. And of course, there are engineers combining their skills and interests to help society. For example, roboticist Johnetta MacCalla, trained in electrical, electronics, and communication engineering, founded a company that uses artificial intelligence to individualize electronic coaching to help kids with diverse needs learn to code and read.

To foster this, engineering schools can bring students' passions out of the informal spaces, such as clubs, student chapters, and personal projects, where they are often relegated. Students need more flexibility to follow their interests, as well as more opportunities to span disciplines and work across teams. Multiple capstone projects and customizable internships are great first steps. Advances in makerspaces and makerspace-like engineering classrooms are another possible way to narrow the divide between formal and informal learning and so enable engineers to get a better education. Loosened from a fixation on formal degree programs, universities might also expand access by allowing certification programs to "stack" into degree requirements and helping students explore engineering-adjacent careers.

Industry must consider its hidden curriculum as well. Companies struggle to find enough engineers who can work with people, communicate across cultures, manage projects, and take a broad view of the social implications of their work. But job postings also demand someone with a narrow specialty—where knowledge will soon become obsolete—instead of thinking about competencies more broadly. Creating engineers who are flexible, fair, multifaceted, and eager to push the boundaries of innovation in an ever-evolving workforce requires deliberate intent. I am inspired by the inventor of the Duolingo language app, engineer Luis von Ahn, an enthusiast for engineering, online games, and languages. Von Ahn refuses to hire job candidates who are rude to the driver who brings them from the airport.

Consider the lifespan

The most important opportunity for upending how engineering's hidden curriculum discourages lifelong learning lies in the idea of the curriculum itself. Engineering education should not stop with a degree. Universities should expand their vision beyond the stereotypical years of higher education and embrace what educators refer to as "K–gray": from early elementary school education into retirement.

Recently, with the associate dean for workforce development and interim dean of my college at the University of Florida, we began the process of outlining a continuum model of an engineer's development—one that considers who students are before and after they pass through our degree programs. We studied our existing offerings plus overarching goals to see where our university placed its resources. We are still iterating the model but I am inspired by its initiative and insight. This kind of regular, formal examination of systems and structures can illuminate the hidden curriculum and so shed light for new solutions and better strategies. We were surprised to find that our offerings focused almost exclusively on undergraduate and early graduate training, with a smattering of outreach to local schools. There was little emphasis on upskilling following a terminal degree, and few offerings geared toward teaching habits and mindsets for lifelong learning.

Again, industry has an important role to play. Engineering faculty and professional engineers rarely communicate, which means faculty know too little about industry's changing needs to adapt their classes, and industry lacks ready access to new research or the academic programs training their future employees. Industry could codesign classes with faculty, which would benefit working engineers, educators, and those in training. Such practices might even help solve two problems at once, since midcareer, senior, and retired engineers are seldom given mini-sabbaticals to expand their expertise. Going further, industry could fuel a virtuous cycle by partnering with educational institutions throughout the K–16 spectrum.

Both researchers and students are increasing access by infusing engineering knowledge into online resources and social media. But as valuable as they can be, content on platforms such as YouTube, Instagram, and TikTok are often created for peers or near-peers and are less likely to reach younger or older learners or those who do not speak English. Any discussion of expanding lifelong learning opportunities must also bear in mind that some individuals and social groups have more access to courses, certifications, and other opportunities than others due to time, funds, and awareness.

Efforts to expand lifelong learning should also go beyond university classrooms and faculty offices into the community. Earlier this year, I was part of a gathering at the White House to discuss how to build the next generation of Hispanic leaders in engineering. A family of four was among the participants. The father, a truck driver, reported he'd never actually met an engineer before; his hope was to help his children gain the education required for a better life. His experience meeting engineers allowed him not only to imagine his children becoming engineers, but to imagine becoming one himself. Not all parents need to be engineers, but parents' familiarity with and attitudes toward engineering need to be considered by admissions officers and other outreach programs. More broadly, universities should consider what influence they can have on families and social circles that encourage a child's inclination to learn.

When I reflect on how I learned to think broadly and persevere, I am grateful to my parents, who taught me to love trying out new things, lessons that helped counter the lockstep assumptions in my engineering curriculum. Their example has helped convince me that foresight and planning can help universities intentionally shift the curriculum (explicit and implicit) to encourage lifelong learning rather than thwart it.

Idalis Villanueva Alarcón *is associate chair of research and graduate studies and associate professor in the Department of Engineering Education at the University of Florida at Gainesville.*