The White Papers

Is it Time to Redesign Engineering?

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Given that the industrial economy has evolved over time, should the delivery of the practice be adjusted to accommodate the needs of different student populations and new technology?

STEM NEWS CHRONICLE

In May 1952, the president of the American Society for Engineering Education (ASEE), S. C. Hollister, appointed a committee to look at the state of engineering education in the United States. The 1955 report, now commonly referred to as the **Grinter Report,** brought about a sea change in the training of engineers and became a foundational document for engineering education.

The “pipeline” concept has long kept people out of the field of engineering. It’s time to address the needs of today’s digital, diverse, global, and rapidly changing society.

How Engineering Education Can Change to Meet The Industry's Needs

With technology advancing at an exponential rate, the effects on the job market have been profound—particularly in STEM-oriented occupations where there is an increasing emphasis on personal skills. To stay relevant in our mission of training human capital in a world where up-to-date knowledge has become so fluid, it is imperative that academic institutions readjust learning outcomes and adapt the educational process as a whole. This can be done by first defining the desired "output" of the educational process and only then looking at how the educational process itself needs to change to achieve this outcome.

What exactly does this mean? At Afeka—Tel Aviv Academic College of Engineering, we refer to this output as our "graduate profile"—the collection of knowledge, skills, attitudes and values required of a graduating engineer when joining the workforce. Crucially, defining this profile first entails understanding industry needs and only then modifying the educational process to ultimately educate graduates who are equipped with all the knowledge and, just as importantly, the skills expected of engineers in the modern workforce.

Although engineering schools around the world have been leading change on various levels, it has now become essential for institutions to embrace a paradigm shift. From what I've seen, the majority of institutions have not taken it upon themselves to define a graduate profile prior to making changes to the educational process they provide students—and this has significant implications for how the industry, faculty, applicants and the general public perceive the relevance and readiness of engineering graduates to meet current industry needs. This results in a skills gap that leads to junior graduate engineers often struggling to secure their first job.

To more effectively meet the industry's evolving needs, engineering education is due for a transformation. At Afeka, we implemented a change in the engineering education we provide our students by applying the same engineering design methodology used in the high-tech industry to develop products. This unique implementation of a well-known methodology entailed defining the qualities of the ultimate "product" or "output" of our educational process—our graduates—prior to adapting the process itself.

The main principles of engineering design—ask, imagine, plan, create, experiment and improve—served as a guide in our journey.

• We began by formulating the problem. The profile of a new engineer, as required by the industry, or in other words, the "output" of the educational process, has changed due to shifting industry needs. But with a new generation of students who learn differently, the "input" to the process has also changed. This can only mean that the process itself must change to remain relevant.

• We then surveyed Israeli high-tech companies to determine exactly what skills they value most in new engineers. This highlighted four main skills: multidisciplinary teamwork, effective communication, self-learning and critical thinking. Taking all findings into account, we then defined our graduate profile to include scientific and engineering knowledge, personal skills, engineering skills, languages, ethics and broad knowledge.

• We divided each skill in the graduate profile into three levels of acquisition (beginner, intermediate and advanced) and then incorporated them into our courses as learning outcomes. This resulted in a continuous educational process during which students acquire the skills.

• Finally, to help achieve these learning outcomes, we created change-inducing platforms that support the adaptation of relevant in-class pedagogy and encourage the formation of extracurricular activities out of class. We also created new learning, teaching and working environments that allow these changes to flourish.

Currently, at Afeka, we are focused on locating tools for evaluating skills in a robust and scalable manner so that student skill levels can be measured after each course, semester and year—and in the future, possibly as an additional admissions criterion for new college candidates.

This unique methodology allowed us to transform the educational process of our students for the purpose of producing graduates that are equipped to thrive in the modern workforce. I think what we learned from this process can serve other academic institutes interested in transforming their own educational processes.

• First and foremost, aim to understand the importance of defining an engineering graduate profile as a mutually agreed-upon goal by all internal stakeholders to serve as a compass. The process of defining the graduate profile together with the relevant management team leads to a commitment of all involved to reach the desired results. But this is not enough—the entire organization needs to be on board with the process. For this to occur, establishing communities based on mutual interests is crucial. Communities around shared activities and goals provide platforms for exchanging ideas and sharing different approaches to coping with the change process—both at the personal and organizational levels.

• Internal communications are also an important tool in advancing change. Constant communication on the part of the administration, along with clear and consistent interdepartmental and cross-departmental messaging and sharing of successes, help engage faculty and staff and encourage internal initiatives that align with the goals of the change process.

• External collaboration is also a must. Higher education is only one link on the educational continuum. Forming an ecosystem that promotes ongoing dialogue and cooperation between all links—from early education through tertiary and higher education and up to and throughout industry employment—is the basis for a coherent lifelong learning process that improves the output at each link and serves national goals.

• Finally, it is important to keep in mind that this type of systemic change takes years to implement and is an ongoing joint learning process. Encouraging trial and error and embracing failure as part of this learning process will lead to faster and better results in the long run—and will ultimately enable engineering education and higher education as a whole to fulfill the essential objective of meeting the industry's needs.

About the Author

Prof. Ami Moyal is President of Afeka – Tel Aviv Academic College of Engineering.

"Exceptional" barriers stop Black students from succeeding in Higher Ed.

Black students face "exceptional" psychological, financial and physical barriers in higher education, according to a new survey by the Gallup and the Lumina Foundation.

Black students are less likely than any other racial or ethnic group to complete any credential or certificate. Researchers say that discrimination, the cost of education and responsibilities outside of school stop Black students from getting credentials — or even enrolling in the first place. Over 12,000 adults this fall, including 1,106 non-Hispanic Black currently enrolled students were surveyed. Here are some of the key findings outlined in the report:

> *"Balancing Act: The Tradeoffs and Challenges Facing Black Students in Higher Education":*

21% of current Black students say they feel discriminated against frequently or occasionally at their institution. Black students were more likely to say they were discriminated against at private for-profit schools (34%), short-term credential programs (32%) or less diverse institutions (31%) .

36% of Black students have responsibilities that interfere with their education, such as caregiving or a full-time job — double the rate of other students.

59% of Black bachelor's students say they need greater flexibility in their work or personal schedule to stay enrolled in their degree or credential program.

46% of Black students with additional responsibilities are more likely to say they considered stopping their coursework in the last six months.

The systemic discrimination that Black students experience in increasingly popular short-term credential programs and at for-profit colleges may point to the need for more oversight, researchers say. Black students' experiences at for-profit institutions is "particularly problematic" given that Black students make up a larger share of the student population at these types of schools than at public or private nonprofit schools.

This research points to the need for leadership at higher education institutions who will address discrimination and its psychological toll, said Courtney Brown, **Lumina Foundation's** vice president of strategic impact and planning.

"There needs to be somebody that's not only going to listen, but take action on that and not dismiss it," Brown told CNN. "Far too many students have tried to report things and it's been dismissed based on the color of their skin, their age or their gender."

She said this data should also serve as a wake-up call for policymakers who have an image of college students as kids who start college at 18, live on campus for four years and graduate.

"We have been trying to educate policymakers about today's students.

How do you think about child care on campus?" Brown told the 74.

About the Author

Courtney Brown, PhD

Vice President of Strategic Impact

Lumina Foundation

The Publisher's Remarks

Our pupils have ranked poorly in international math exams for decades. For over four decades there has been a sort of "math war" in which we have focused on reducing racial inequality (the gap) in math because we were losing ground to China, India, and other Asians. The economic ramifications would be dire if we do not change. We are now in a tech/math driven economy where computer science dominates and drives further education and income inequality. A math gap in schools, in essence, is merely a preview for accelerated income inequality.

When computers and "group learning" became the vogue, we pushed students to learn keyboard manipulation rather than having them acquire problem solving skills and learning arithmetic. The fear of growing economic inequality drives much of education reform because of competition from our geopolitical foes and from interests within.

Can achievement gaps be better addressed by applying culturally based alternatives to tracking students' achievement in math? The anguish over math is not entirely about what kids actually learn in their classrooms, or how well those lessons prepare them. The elephant in the school board room is the reluctance among leadership to overcome their personal bias and to make the difficult choices to provide under-achieving students the remedial support required.

If a student does not understand how an equation works (ie Pythagorean or polynomial), he/she may also fail not only math but the social, economic, and policy rules which will further contribute to disparate social and economic outcomes. social inequality. But a student who does not understand how an equation works can fail at both math and social policy.

Lawrence P King

Points Discussed with College Deans About Engineering Education Change

Many students today are experiencing their education on-line. Among questions raised, does the delivery system serve the needs of students, the institution, research, and industry?

Subject modules include videos, lectures, and an associated quiz. Videos cannot stand alone so some text need to be more explanatory and, in some instances, more specific.

The engineering profession has changed enormously but teaching over the last 50 years hasn't kept pace with social, cultural, and ethical change. Many years ago, the focus was very narrow, and an engineer was trained to do one aspect in engineering that wasn't focused on management or leadership. Today, the engineering profession is very broad, and that is one thing that we want students to become: a broad-minded thinker in engineering to be inclusive of social sciences.

Engineers should move away from thinking that they are graduating as a electrical, civil, or mechanical engineer, and rather think about how the field serves the changed public and potential career paths available in the future.

The big international and national drivers that engineers should focus on are economic disparity, infrastructure, climate change, altered and energy sources, medical equipment devices, and the continual development of computerized systems and artificial intelligence. These will all become emerging career paths for engineers in the future.

Engineering students should expand their focus on broadening their minds and interconnecting with people of many cultures with a range of different needs.

Having this ability will engineers to think about solving some of the enormous problems that challenge us today and in the future.

As the sea levels are rising, the structures that we built must be resilient, so it is important to design for different kinds of loads, pressures, materials, and project durations.

Engineering students need to be prepared create a form of self-awareness to determine who they are and what they want to achieve in their lives. This will help provide a sense of self-satisfaction, professional satisfaction, and professional growth required now and in the next decade. Once they determine who they are, they can start thinking more broadly about the problems to be solved in this world.

Sources: Dr. Willie Rockward, COE Morgan State University, Dr. Daniel Knopf, Assoc Dean UT

Education researchers partner with STEM instructors to make courses more inclusive

Stanford Report

Jocelyn Nardo, a first-generation scholar and the daughter of Cuban immigrants, remembers a discouraging moment from her undergraduate days at a Florida university: After taking a class in forensics, Nardo discovered an affinity for science and decided to change her major from English to chemistry. Her advisor gave her two duplicate forms.

Jocelyn Nardo

“She said, ‘You’ll end up changing back,’ recalled Nardo, who not only defied her advisor’s prediction but went on to earn both a master’s degree and a PhD in chemistry.

Now a postdoc at Stanford Graduate School of Education (GSE), Nardo is focused on easing the barriers that might deter other students from pursuing a STEM education. As a researcher with the new IDEAL Research Lab at Stanford, she and other postdocs, students, and faculty work to identify challenges facing historically marginalized university students in STEM, and partner with instructors to apply educational principles to redesign courses in ways that promote access and a sense of belonging.

Shima Salehi

The lab is directed by GSE Assistant Professor Shima Salehi, who studied electrical engineering as an undergraduate at Sharif University in Iran before earning her master's and PhD in learning sciences at Stanford. The work of the lab is partly an extension of some of her own research developing evidence-based interventions to support underrepresented college students in STEM.

"We're taking principles of learning and cognition and bringing them into day-to-day classroom practice, in a more equitable way," Salehi said. "It's about creating a stronger bridge between the theory of learning and the practice of teaching. We're designing activities and tools to provide a more scaffolded learning environment for students."

The IDEAL Research Lab is a component of the larger IDEAL initiative at Stanford, which emerged from the university's Long-Range Vision to ensure inclusivity, diversity, equity, and access in learning environments.

"One of our objectives with the IDEAL initiative is to apply research and expertise to the challenges facing students – to study the barriers to equity and then use that evidence to improve our practices," said Dan Schwartz, the I. James Quillen Dean of the GSE and the Nomellini-Olivier Professor of Educational Technology, who is the founding deputy director of the campuswide IDEAL initiative.

Targeted strategies address students' needs

Since its launch in 2020, the lab has taken on several projects concerning equity barriers in introductory science and engineering courses at Stanford.

A course on principles in chemistry, for example, which focuses on teaching concepts and problem-solving skills, meets prerequisite requirements for a variety of majors, from earth science to mechanical engineering. Many pre-med students also enroll, well before settling on their major. "This course is one of the most important gateways for students interested in STEM," Salehi said.

But some, especially first-generation and underrepresented minority students, enter the class at a disadvantage – if they come from a high school that didn't offer AP or honors courses, for instance, or one that had less experienced teachers.

A two-quarter sequence, Chem 31A and B, was introduced in 2004 as an alternative to the original 10-week course, giving students with less preparation a longer runway to master the material. A placement test for incoming students helps determine who would most benefit from the two-quarter option instead of the original section (Chem 31M).

Students who need more time to get up to speed in this course often face other pressures and demands on their time, compounding the difficulty, said Jennifer Schwartz Poehlmann, a senior lecturer of chemistry at Stanford, who coordinates and co-teaches the first-year chemistry sequence.

"They might have one or more jobs, or they might be struggling in multiple classes, so they need support in those, too," she said. "The hours just add up for these students."

Reducing the amount of material covered in the course isn't a viable option, Poehlmann added. "The problem would then become that [students] won't be prepared for subsequent courses – it would set them up to fail in a later course where they would lack key skills or knowledge," she said. "It takes time to learn science. There's no way to sugarcoat that."

In the years since, the instructional team for Chem 31A and B has continued to pursue strategies for supporting students, including a robust mentorship program introduced in 2020 that provides personalized mentoring and tutoring, as well as support around belonging and well-being.

The IDEAL Research Lab got involved that year when Natalie Chapman, then a Stanford student majoring in mechanical engineering, undertook a research project through the GSE's undergraduate honors program in education. With Salehi as an advisor, Chapman interviewed 57 students who had taken the introductory chemistry sequence in recent years, 60 percent of whom identified as first-generation/low-income.

An analysis of the findings by Chapman, Nardo, and other researchers at the IDEAL lab found that students who had less preparation in high school struggled with certain course elements such as lab worksheets, practice problems, and group work.

Drawing on her expertise in both chemistry and education principles, Nardo worked with Poehlmann to address some of the components students found challenging. For starters, she adapted a problem-solving template that Salehi had developed for physics as part of her dissertation research, tailoring it to chemistry; Poehlmann then customized it further to the course itself. The template walks students step by step through the process of unpacking a complicated chemistry problem, including clarifying the task at hand and identifying the relevant skills and concepts needed to solve it.

"Often students get to a problem and they're like deer in the headlights – they don't even know where to start," said Poehlmann. "The problem-solving template helps them to get through it on their own, and then to make connections and use the knowledge they just gained to solve the next problem." The IDEAL lab also helped develop and implement a once-weekly supplemental problem-solving session, which Poehlmann said instantly generated double the attendance she found with office hours.

Another project the IDEAL lab has taken on involves an introductory sequence in mechanical engineering, also focused on concepts and problem-solving. The team, led by Fred Krynen, a doctoral student at the School of Engineering, designed targeted activities for each of the course's weekly learning goals, creating opportunities for students to receive timely and specific feedback they could incorporate to improve their performance going forward. The changes to the course debuted this fall, and the researchers will closely monitor their impact.

The lab is also working with the math department on a problem-solving template tailored to an introductory sequence of calculus courses. And an economics instructor recently reached out to Salehi for guidance in making an introductory course more appealing and engaging for a diverse body of students.

"It's really fulfilling," Salehi said. "I love having this close collaboration with instructors – hearing their desire to teach better and helping them to do that."

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End the "Pipeline" Mindset

The pipeline analogy, which suggests that young learners join a pathway of knowledge acquisition that ultimately results in an engineering degree, has impeded efforts to diversify engineering. A pipeline has only one entry point and one exit point. If a student enrolled in the wrong math class in 7th grade, or if her high school didn't offer advanced math courses, she will find it difficult to become an engineer. Few 7th graders have engineering on their radar, yet their choices in what classes to take could shut them out of engineering—unless they're willing to go back and enroll in remedial math courses to make up for their lack of foresight as a 12-year-old. This is not an attractive proposition for most. What if the tenacity of students who arrive in our engineering programs without the benefit of such foresight was recognized and rewarded instead of punished?

Instead of forcing our students to memorize the intricacies of the chain rule in taking derivatives, would it not be better to teach them to use mathematics to model physical phenomena?

It is widely acknowledged that engineering educators have designed curricula meant to keep people out. The curricular structure is rigid, with long prerequisite chains and few free electives. For example, all of our students are forced to take three semesters of calculus—even though the vast majority don't really need that. In a sense, students are subjected to one to two years of academic hazing before they are allowed into "the club" of professional engineers.

About the Authors

Issues in science and Technology, Sheryl Sorby, past president of the American Society for Engineering Education and professor in the Department of Engineering Education at the University of Cincinnati.

Norman L. Fortenberry is executive director of ASEE.

The future of engineering education in Canada

Engineering Deans Canada adopts a statement of principles by institutions responsible for engineering education. The Calgary Declaration on the Future of Engineering Education *is a Call for Action on the need for change, based on the following broad fundamental principles.*

April, 2023

Change

We, the members of Engineering Deans Canada*, believe that the roles engineers are called to play in society and the context of engineering practice are changing at an unprecedented rate.

Leadership

We believe that, whether it be due to the globalization of economy and trade, the complexities of humanity's urgent grand challenges, the accelerating pace at which technologies develop and are becoming inextricably-linked with our daily lives, or the growing public demands for technological accountability, engineers can and must assume a leadership role through their critical work – not only as practicing professional engineers, but also along the many career paths they choose to follow over their professional lives.

Engaged Citizens

We believe that to define the role of engineers simply as utilitarian problem solvers does not do justice to our profession's potential. Rather, engineers are uniquely qualified to play an important role in civil society to create opportunities that will ensure the prosperity of our communities, Canada and future generations. They must be educated to be engaged global citizens who see obstacles to prosperity and societal well-being as problems that are theirs to solve.

Evolving Curricula

We believe that, to prepare the next generation of engineering professionals, fundamental changes in education are required to ensure that graduates are equipped to adapt to a rapidly-changing scope of practice. Such changes must encompass not only the subject matter of professional programs, but also the manner in which teaching and learning occurs. We must ensure that students derive the most from their educational experience and are prepared to thrive in a world where the knowledge base and tools at their disposal continually evolve and expand.

Inclusivity and Diversity

We believe that Canadian engineering programs provide an educational backbone and valuable skillset that is highly applicable and important in today's technology-pervasive society. This education must be inclusive and accessible to everyone to ensure that the engineering profession benefits from diversity of thought and practice.

Adaptability and Resilience

We believe that the education provided to Canadian engineering students must adapt in a timely way to the changing requirements of our world. Hence, the needs of higher education and accreditation must co-evolve in a sustainable way, striving to achieve a balance in the depth and breadth of education required for engineering practice and to ensure that graduates are prepared to be resilient in the face of change.

Commitment

We believe that engineering professionals deliver a unique value to society, one that higher education institutions have an obligation to foster and provide. Therefore, we, the members of the Engineering Deans Canada*, commit to fulfilling this obligation and call on our partners to work with us to drive substantive change in engineering education for the benefit of our profession and broader society.

Canada should support diversity in STEM to encourage innovative Research.

Attracting and retaining diverse students in the STEM disciplines (science, technology, engineering and mathematics), especially those from Black, Indigenous and Latinx backgrounds, has been a long-standing issue in North America.

Although there's a history of research on under-representation in STEM, the needle has not moved much. This is because existing research and policy has focused on assimilating students rather than examining existing societal and institutional barriers to STEM majors and careers.

With recent equity-oriented research shifting to examining and transforming institutions, Canadian higher education is positioned to leverage what we already know about why Black and Indigenous people are underrepresented in the sciences. Examining these issues in the Canadian context can help us transform STEM teaching, learning and practice spaces to be more welcoming of diverse students and perspectives.

About the Author

Jennifer D. Adams, Tier 2 Canada Research Chair of Creativity and STEM and Associate professor at the University of Calgary

This is the abstract from the book by Dr. John Rudolph, which addresses teaching of science that is worth reading.

Abstract

This chapter describes the primary reasons we have historically taught science in school. These are science education for culture, better thinking, utility, and democratic decision-making. The utility argument has three versions—science education for personal utility (that is, learning science to solve everyday personal problems, like repairing a broken lamp), national security (that is, science for weapons development and defense technology), and economic growth (science for technological and industrial innovation). All of these are typically divided into two categories: science education for technical training (that is, preparing future scientists and technical workers) and science education for general

education (that is, science for the citizen.)

John L. Rudolph, Professor of Science Education – University Wisconsin

• Presents a concise overview of the arguments for teaching science in schools,

• Challenges the widely accepted belief that science education should primarily focus on preparing students for science-related careers,

• Offers evidence to question the current focus on science content learning in schools,

• Invites policymakers to reconsider whether science education should continue to focus on technical training in preference to science teaching for general education.

A Message from the Editorial Planning Board

Engineering education is the activity of teaching knowledge and understanding of scientific principles and applications to the professional practice of engineering.

It provides instruction on the application of science for the optimum conversion of nature's resources to the uses of societies around the world. As society has evolved, the creative application of "scientific principles to design or develop structures, machines, apparatus, or manufacturing processes will also evolve.

Dr. Irelene Ricks – Policy Consultant HUD

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Frank Robinson, Jr. - Director of Operations – After School Programs at Science, Technology, Engineering, Math & Medicine (STEM2) HUB

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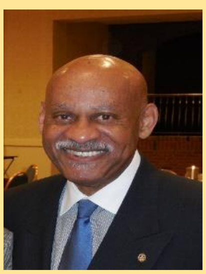

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