FALL 2021

Three Stanford Faculty Write about Change & Engineering Education

SHERI SHEPPARD

R. LANIER ANDERSON

TOM KENNY
Stanford University
Palo Alto, CA

ABSTRACT

Stanford has always embraced educational change, but not for its own sake. Instead, we have pursued reforms in response to specific problems or to realize definite possibilities. In that sense, our curricular innovations seek to move purposefully from *what is* to *what might be*. Such purposeful change is guided by underlying values grounded in our commitment to a broad liberal education model. We want our students to develop disciplinary knowledge, skills, and abilities (KSA), but also ways of thinking and knowledge beyond their specialized fields. We want their education to profit them individually, and also to position them to help their communities and the wider world. Our dual goal of disciplinary KSA in concert with a broad liberal education does give rise to tensions. After all, university study with an exclusively disciplinary focus (as is normal in European higher education), or with a purely liberal arts orientation (offered in many smaller U.S. colleges) could easily fill an entire undergraduate experience.

In this essay, we offer some historical and contemporary examples of educational change at our University. Each illustrates the inherent tension at the heart of Stanford's ongoing efforts to situate engineering education within liberal education—a tension that calls for innovative thinking and approaches.

Key words: Diversity concerns-student diversity, institutional change, accreditation-ABET

INTRODUCTION

In this essay we consider engineering undergraduate education at Stanford in the larger context of University values and professional standards. As we illustrate, University values have historically influenced the makeup of an engineering undergraduate experience. Their influence is still present, and they challenge Stanford faculty to think creatively, critically and innovatively about how a modern undergraduate engineering degree should serve an increasingly diverse set of learners who must operate in a world of expanding complexity. We begin by looking at some of Stanford's founding principles, followed by a modern case study of an engineering undergraduate program where the faculty have attempted to balance these principles and formal professional requirements. We end with a glimpse into real-time University-level decision-making that may impact the face of undergraduate engineering at Stanford.

We offer this essay as an example of engineering education innovation being intrinsically and dynamically connected to the aims of liberal education as a whole. When speaking of "liberal education," we bear in mind both what such an education fundamentally is and the main benefits it is supposed to bring to students. On the first point, liberal education affords students freely-chosen educational pathways within a set of constraints designed to ensure a degree of breadth in their educational experiences—as opposed to higher education focused entirely on training within a specialized discipline. On the second, the broadening demands of liberal education are supposed to promote the development in our students of key capabilities in critical thinking, a more cosmopolitan outlook, and exposure to a range of disciplinary ways of thinking helpful to their formation as broad-minded citizens of a diverse modern society.

STANFORD—A DIFFERENT KIND OF UNIVERSITY, EDUCATING A DIFFERENT KIND OF ENGINEER

Founding Ideas—Innovative Roots

Our founders, Leland and Jane Stanford, envisioned a different kind of university, robustly engaged with the surrounding society. Stanford's Founding Grant aims to "promote the public welfare" by "qualify[ing] its students for personal success, and direct usefulness in life" (Stanford University 1987, 4). Jane Stanford insisted that the University be co-educational from the beginning, so that Stanford women would feel full ownership as members of the institution. Stanford also sought to make higher education more accessible; in the early years, tuition was free or minimal.

The reform-minded Stanfords were attracted to the "elective system" pioneered at Cornell University, which abandoned the traditional curriculum centered on classical languages and permitted students to focus instead on scientific and technical subjects, modern languages, or the social sciences. Notably, the Founding Grant provides for facilities like "mechanical institutes," "museums," etc., to support a wide range of practical subjects. Stanford thereby committed to an expansive version of liberal education, which grounds students in a broad study of the sciences and liberal arts, while also providing access to technical and professional studies. The engineering fields were always an integral part of this picture: Five of the first fifteen faculty members were engineers, around 25 percent of the initial students pursued engineering, and prominent early graduates (e.g., Herbert Hoover) entered engineering professions. Hoover's career exemplified the Stanford goal of engineering education "in behalf of humanity and civilization" (Stanford University 1987, 4).

To lead their University, the Stanfords selected David Starr Jordan, a Cornell graduate who was President of Indiana University (IU). Jordan had implemented a version of the elective system at IU in the 1880s (Jordan 1922, 293–4). That curriculum preserved a required program during the first two years, but devoted the later years to a major field elected by the student. Jordan leapt at the opportunity to extend his experimentation at a new university in the West, with a faculty he could select. At Stanford, Jordan radicalized the IU curriculum into the "major system" of higher education.

The Basic Idea of a "Major" and the Power of Departments

The Stanford major system was conceived as a program for individualized, elective-driven education. As Jordan described it,

> The unit of faculty organization would be the professorship rather than the department. Each student, therefore, must choose a major professor who should be his adviser, and in whose department he must take enough courses to fulfill certain requirements. As minor subjects or electives, all classes would be open to any student intellectually ready for the work. To secure the Bachelor's degree, each candidate would be obliged to satisfy his major professor and to complete enough other work to fill the conventional four years. … The largest liberty consistent with good work … was to be granted to the student. (Jordan 1922, 358)

Originally, then, each student worked out an individualized curriculum for the entire four years with a major professor chosen upon entry to the University. The new system laid down an ethos of educational decentralization: Jordan had the adage "Every professor sovereign in his own department" (Stanford University 2012, 18). Clearly, though, the efficiencies of standardizing major curricula at the department level were powerful, particularly once departments grew and "sovereignty" had to be jointly held. Within fifteen years, departments had assumed full control of Stanford majors.

Majors were generally supposed to claim only one-third of the total effort required for graduation (40 of 120 semester units). This afforded ample space for the free exploration so important to Jordan. But it was already clear that such a limited curriculum was insufficient for engineering. Applied science disciplines were exempted from the cap, and some exceeded it by a great deal; the major in mechanical engineering, for example, required 65 units of engineering courses, plus an additional 47–8 units of applied mathematics, physics, chemistry, and metallurgy, thereby consuming up to

113 of 120 total semester-units. The special treatment of engineering revealed internal tensions that have continued to affect the Stanford major system to this day. The central issue pits liberal education's aim to provide exposure to many fields against the major's goal of intensive specialist training.

Jordan's second legacy—decentralization—has exacerbated this tension over the years. Stanford professors are all now appointed within departments, so none are individually sovereign within a field. But decentralized academic planning persists. Departments have been permitted to establish and revise major requirements without strong centralized control, and major curricula have effectively been captured by the specialist disciplines. As a result, Stanford majors show unusually great variation in their demands upon students.

Engineering majors have traditionally been the most demanding. We have therefore faced a consistent challenge to secure our students the benefits of a broad liberal education together with the specialist training they need to be successful engineers.

EVOLVING AN ENGINEERING PROGRAM TO FIT STANFORD AND PROFESSIONAL STANDARDS: 2015

Now we fast-forward to 2015 for an example of change in the Mechanical Engineering (ME) major that illustrates how independently operating departments can confront that challenge of meeting both Stanford and professional standards. By 2015, Stanford's overall undergraduate population was over 7000 students and nearly 50:50 women and men. The School of Engineering had nine departments, offering 18 major areas of study (Stanford University 2014) that led to a Bachelor of Science. ME undergraduates, some 25 percent of whom were women, represented the second largest major within Stanford's School of Engineering, and the ME undergraduate program was highly regarded externally. The structure of the 2015 ME degree had been largely unchanged for over 30 years (though it was very different from the early 20th century programs described above), and offered students essentially a single path through the major. Of the 180 quarter-units required for a Stanford degree[1], ME "laid claim" to 117 (66%)[2]. Much of the overall structure of these 117 units was dictated by ABET[3], an international engineering accreditation organization. ABET had a prescribed program accreditation process that involved going through an extensive self-study and external review process every six years to confirm achievement of learning criteria related to analytic and

[1] In 1917 Stanford converted from the semester system to the quarter system; 180 quarter-units represents 120 semester-units

[2] In addition, the university had imposed more "general education" requirements

[3] Formally known as the Accreditation Board for Engineering and Technology

design skills, communications abilities, teamwork and life-long learning, and awareness of ethics and social context.

The Importance of Data for Prompting New Thinking

In the fall of 2015 the Undergraduate Curriculum Committee (UGCC) in the ME Department presented at a faculty meeting data from the spring 2015 Senior and Alumni surveys on how the department was doing relative to its program's educational objectives and outcomes. These data were generated as part of the department's ABET self-study process, and while they suggested it was doing well on many of the measures, there was room for improvement: *We could do more to help our students learn to function on multidisciplinary teams and understand professional and ethical responsibility, as well as use modern engineering tools necessary for engineering practice*.

Furthermore, the open-ended comments offered by seniors and alumni indicated the need for the program *to give students more choices, use more modern technologies and industry-inspired examples and projects, and challenge students to explore in depth areas within ME that are of interest to them*. The implications of these data interacted in departmental discussions with ideas from several other sources, including our review of ME programs at other leading U.S. engineering schools, models emerging in the other engineering departments at Stanford, recommendations from the ASME Vision 2030 report (ASME Board on Education, V2030 Project Group 2012), and pressures from increasing enrollments. The UGCC then took on the challenge of redesigning the BSME degree during Academic Year (AY) 2015–16.

Slow and Steady Development Leading to the BSME 2.0: 2015–2018

Throughout AY 2015–16 many faculty, beyond the UGCC membership, were involved in the redesign effort, which became known as the BSME 2.0 (BSME, Bachelor's of Science-Mechanical Engineering). Faculty-teams explored (and debated) possible concentrations and tracks, core fundamentals for all ME majors to know and do, a "slimming" of the major that could still prepare graduates for professional practice and/or graduate school, as well as new models of capstone experiences and advising. The UGCC, in partnership with the department chair and the director of student services, considered implications of the new program on resources (faculty, staff, course assistants, supplies and spaces) and advising. In the spring of 2016, we pressure-tested potential shortcomings by hosting an afternoon ME Undergraduate Summit exclusively on the redesign and a student focus group to solicit additional student input. This culminated in a formal BSME 2.0 proposal, which was passed unanimously by the entire ME faculty in June 2016.

The department's endeavors in redesigning the ME major over AY 2015–16 illustrate the decentralized nature of majors at Stanford (harkening back to Jordan), as there was little conferral with the School of Engineering about the proposed changes, much less any review and approval at the School or University levels. The result also revealed the tension that engineering faculty attempt to balance between designing majors that recognize (and value) engineering in the larger context of a liberal education, and that train students who are well respected in the larger engineering community.

During the next two academic years, new courses were piloted and modifications were made to existing courses. This led to the official launch of the BSME 2.0 as the new ME major in the fall of 2018. The redesign effort was successful in part because faculty acknowledged four key points upfront: 1) a four-year engineering undergraduate degree is too short of a time to educate a "fully formed engineer," 2) faculty and students should share responsibility for defining which KSA (knowledge, skills and abilities) are crucial for the major, 3) the new structure should be "changeable" as student and faculty interests change, and 4) the major would remain an ABET-accredited program (which adds up to a minimum of 113 quarter-units) that is intent on achieving a set of professionally-established learning outcomes[4] for our students.

While the overall structure of the BSME 2.0 may not appear to be highly innovative, its design and implementation do represent a significant shift in faculty thinking. In our new paradigm, the ME faculty *as a whole* take responsibility for all core learning objectives for Mechanical Engineering students, rather than devolving responsibility to the specialized subfields. This more collective way of thinking has opened the door to more and deeper discussions among the faculty about *what we teach*, *how we teach* and (perhaps most importantly) *how students learn*.

Launched in 2018, with More Work to Do

In the BSME 2.0, represented in Figure 1, students have 42 quarter-units in the ME core (agreed on by the ME faculty collectively) that establish a foundation in knowledge, skills, and abilities key to Mechanical Engineering. The associated courses aim to achieve the ABET learning outcomes (see

[4] In 2015 there were 12 ABET learning outcomes. As of 2019, the ABET learning outcomes have been revised to seven; the BSME 2.0 has been adapted to these. Students should acquire to:

1. identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. communicate effectively with a range of audiences
4. recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. acquire and apply new knowledge as needed, using appropriate learning strategies

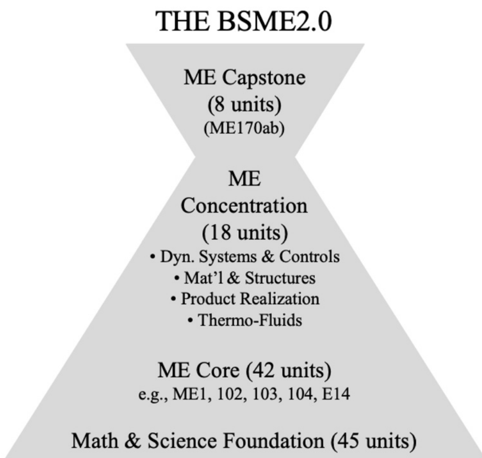

Figure 1. Abstract Representation of the BSME 2.0.

footnote 4), with special attention being given to "identify, formulate, and solve complex engineering problems" and "apply engineering design to produce solutions that meet specified needs." The core begins with ME1: *Introduction to Mechanical Engineering*, designed to allow students to determine if ME is a good fit by introducing key tools (e.g., MATLAB, CAD), concepts (e.g., free-body diagrams, control volumes), processes (e.g., design, analysis), and role models (e.g., guest speakers). It ends with a 2-quarter capstone experience, ME170ab: *Mechanical Engineering Design: Integrating Context with Engineering*, developing projects with real clients.

Students declare one of four concentrations for another 18 units; a concentration enables a student to focus more in-depth in a particular ME aspect that is of interest to them. This, in combination with a year of math/science (required by ABET) adds up to 113 quarter-units. Students have University requirements beyond the 113 units—including studying a foreign language, general education courses in writing and college-level learning, and breadth requirements that expose students to other disciplines and ways of thinking. These requirements, as well as the number of units that should be required for a major, are currently under debate as discussed in the next section.

It is noteworthy that the launch of the BSME 2.0 coincided with our ABET reaccreditation; we are happy to report that our program has been reaccredited until 2024[5]. Furthermore, its less-rigid structure has enabled faculty to introduce new and novel courses (e.g., ENGR217: *Expanding Engineering Limits—Culture, Diversity and Equity*; ME267: *Ethics and Equity in Transportation Systems*). However,

[5] The ME major was first accredited by the American Engineers' Council for Professional Development, the predecessor to ABET, in 1936

there is more work to do to "fine tune" and improve the BSME 2.0 so that it is fully accessible to any matriculating student (regardless of their high school background), has greater coherence (and less redundancy) of topics between courses, makes greater use of active-learning strategies, and continues to evolve with student and faculty interests. An interim/internal review of the BSME 2.0 was planned for AY 2020–21, but has been postponed a year because of faculty attention being re-focused on developing and delivering online courses for AY 2020-21 due to the COVID-19 pandemic.

WHAT SHOULD A MODERN STANFORD MAJOR LOOK LIKE? A QUESTION UNDER DEBATE

A Stanford education continues to be comprised of University requirements intended to prepare students to think about big questions and department-selected content in the major that provides specialization within a discipline. Stanford frequently re-examines the University-wide requirements, but it tends to leave the department-specific content for the departments to define (as illustrated in the previous section). In AY 2017–18, however, a Design Committee[6] was convened to take a University-wide look at the role of the major within Stanford education.

Current State of the Major System at Stanford and its Challenges

The freedom granted to departments to define content has had two consequences:

- Stanford majors have been "captured by the disciplines," in that they have evolved to reflect disciplinary self-conceptions and the educational trends within each field. Pre-2018, Stanford majors varied in unit demands from 55 to 135 quarter-units (inclusive of pre-requisites) out of 180 required for graduation, and in internal structure from largely flat to highly laddered.
- This variation in the basic features of an undergraduate major reflects an underdeveloped institutional vision for the major's educational role as a part of liberal education. Unfortunately, this promotes the notion that the only role of the major is to provide vital vocational training that plays an outsized role in defining the future of Stanford graduates.

These distinctive features of the Stanford major system pose two key challenges for our present and future:

- The growth of specialized knowledge may result in increased demands within some majors that could jeopardize the *accessibility* of all majors for all Stanford students. Some of our best students arrive at Stanford without Advanced Placement credits or other advanced preparation

[6] The 16-member Design Committee was led by co-authors L. Anderson and T. Kenny, and was made up of senior faculty and lecturers, as well as senior administrators in undergraduate education and development. It was complemented with a standing focus group of 15–20 students from all four classes and majors from across the University, with whom the Committee regularly conferred.

in key subjects. We must ensure that all students have the space to learn what they need to be successful in the major of their choice.

- The lack of a shared institutional vision about the major's educational role and proper internal structure is a growing challenge to the *transparency* of our system. Some students struggle to make informed decisions among majors as they explore their interests, and the lack of common structure contributes to the false, exclusively vocational conception of the major.

Main Policy Recommendations: Unit-Load Reform and Capstones

The Design Committee proposed recommendations to advance two, mutually reinforcing goals (Stanford University 2019). First, the major should provide a first-hand experience of *what it is like* to understand and perform within a discipline at depth, without requiring comprehensive coverage. Second, the demands of an undergraduate major on the students must remain at a level consistent with their reasonable engagement with the many other aspects of a full liberal education so that our graduates leave Stanford as broad-minded, creative, and resourceful thinkers, prepared to face challenges that we cannot yet even imagine.

After broad faculty discussion throughout **October 2019**, including five Town Hall meetings engaging faculty across Stanford's three undergraduate-training Schools (Earth, Energy and Environmental Sciences; Humanities and Sciences; Engineering), the Committee's recommendations were deliberated within the Academic Council Committee on Undergraduate Standards and Policy (C-USP), and then presented to Stanford's Faculty Senate[7], for approval at the end of AY 2019-20. The first two recommendations, which relate directly to the form of the major, were that:

- No majors should impose requirements amounting to fewer than 60 or more than 95 quarter-units of coursework, inclusive of necessary pre-requisites. This recommendation does not define the size of the major as narrowly as many peer institutions, but adopting a range that extends from one-third of total student effort to just over one-half does send a clear signal that the major should occupy substantial, but limited, space within the student's complete education. We believe this size profile will be compatible with the other goals of liberal education, including first-year general education, global exposure, and robust educational breadth.
- Every Stanford student be required to complete a substantial capstone experience that integrates important elements of the undergraduate experience and culminates the student's

[7] As described at https://facultysenate.stanford.edu/: "The elected [Stanford] Faculty Senate is the centerpiece of academic governance at Stanford and the main instrument for faculty participation in setting policy and making decisions on academic affairs. The work of the Senate and its committees-the Steering Committee, the Committee on Committees, and the Planning and Policy Board-is supported by the Academic Secretary's Office."

undergraduate intellectual development at Stanford. The capstone would provide a clear focus around which elements of the major can be organized by serving as the telos of the student's education; introductory, breadth, and depth elements of the major could be oriented toward it.

Feedback-to-Date: March 2020 and Beyond

Concerns arose from the Town Halls and C-USP debates that the 95-unit "cap" would not afford enough room to develop disciplinary KSA indispensable to student success, particularly within engineering. As a result, C-USP forwarded a modified recommendation to the Faculty Senate that raised the cap to 100 units. The proposals prompted extensive discussion at a special in-person Faculty Senate meeting on **March 5, 2020**, where small (circa 8 members) groups were formed to facilitate active and exploratory debate.

A second full Senate meeting was held on **May 7, 2020** (via Zoom to accommodate conditions brought on by the COVID-19 pandemic) for formal deliberation of the unit-cap proposal. At that meeting, faculty associated with some currently high-unit majors, particularly within engineering, continued to express concerns that the proposed unit cap imposes an arbitrary constraint on the content necessary for success in a discipline. While the reforms left the specification of major learning goals up to expert faculty in the departments, the proposal did introduce new constraints on those decisions through the unit range "design target," intended to ensure accessibility for all students. This disagreement led to vigorous debate about how best to balance local expert judgments on how much content is needed to achieve major learning goals against the whole University's interest in the universal accessibility of majors.

The Senate passed the unit-cap proposal on a divided vote, which did not allay concerns within the School of Engineering regarding the unit cap proposal. In the following weeks, a petition circulated calling for a special meeting of the entire Stanford Academic Council (whose membership includes all tenure-line faculty at the University) to reconsider the decision. The petition attracted sufficient signatures, coming largely, though not entirely, from engineering faculty, and on **June 23, 2020** the Academic Secretary convened the first special meeting of the Academic Council since the Vietnam era of 1970.

The meeting did not achieve quorum, preventing any binding decisions, but both proponents and opponents of the proposal agreed to proceed with a full discussion of the educational issues raised by the Senate decision. The petitioners argued in favor of the University's traditional decentralized decision-making model for majors (i.e., each department determines its own major requirements) vs. the reform proponents who argued to preserve the liberal education model (i.e., the University plays a role in determining what percentage of total student effort may reasonably be claimed by the major) and for the whole University's interest in the accessibility of majors. Another major topic of discussion was an exceptions policy. The original Senate legislation envisioned exceptions only for departments with ABET accreditation, but some engineering departments that had departed from ABET asserted they could present just as strong an intellectual case for exceptions treatment as could ABET programs like Mechanical Engineering.

Despite lacking quorum, all parties agreed that the depth of disagreement and importance of the issues raised for our students' education called for a compromise proposal. The Senate Steering Committee therefore brought an amendment focused on a broadened exceptions process to the Faculty Senate on **October 22, 2020**[8]. The amendment specified that:

- "Any major that is accredited by an external accreditation organization, such as ABET, is exempted from complying with the policy if the 100-unit limit is too low to meet the organization's standards or expectations.
- Any department that offers such an exempted accredited major must also offer a unit-compliant major for students who do not wish to pursue the accredited major.
- Any department or program may seek an exception from the 100-unit limit under a review and approval process outlined in the amended policy."

The exceptions review is two-sided and will rely on good faith: The department submits documentation detailing their efforts to make the major as accessible as possible for all students, and the School Dean and a University-wide committee that reviews undergraduate majors will make the final approval decision, while honoring local specialist judgments about how much coursework is genuinely necessary to develop the essential disciplinary KSA.

The Steering Committee's amended proposal was passed by the Senate on a unanimous vote. This revised legislation, which goes into effect for AY 2023–24, attempts to balance student accessibility to majors with professional standards, and adopts a compromised approach to where curricular decision-making happens. Time will tell as to whether this will result in engineering degree programs that inspire and serve our increasingly diverse student body by promoting "the public welfare" by "qualify[ing] its students for personal success, and direct usefulness in life" (Stanford University 1987, 4).

CLOSING REFLECTIONS

The central tension between specialization and breadth-building exploration will continue to challenge Stanford engineering education in the decades to come. We believe, however, that our historical educational values provide useful guidance. Jordan was right to emphasize the importance of free intellectual

[8] https://news.stanford.edu/2020/10/23/faculty-senate-hears-provosts-budget-report/

exploration, and we endorse the University's early commitments to bring more students into higher education and ensure that every field of study is accessible to all students. At the same time, without meaningful specialization, our students would lack an essential feature of the university-trained mind. We must therefore balance depth and breadth, not only in the student's overall undergraduate experience, but also *within the major curriculum* itself; this is therefore a significant innovation challenge for us.

We strike this balance best by focusing design efforts on the needs of students first, rather than putting the shape of the discipline first. The growth of specialized knowledge is indefinite and accelerates by the year. Already, full mastery of all subfields within a discipline is an unrealistic goal for a four-year undergraduate program. We must accept this reality. We can train engineers equal to the challenges of tomorrow only by giving them the tools and the motivation to become lifelong learners. That fact should guide our curricular efforts. Students need a genuine exposure to key subfields within the discipline, so that they understand the shape of the field well enough to guide future learning. But they also need real depth in at least one subfield, since firsthand knowledge of what mastery is like is an indispensable instrument in the mental toolkit of the lifelong learner. Our proposal for the BSME 2.0 aims to strike this balance, identifying a reduced ME Core that gives our students the needed breadth *within* Mechanical Engineering, while affording students more flexibility to pursue their own engineering interests complementing a concentration that provides subfield depth. A robust capstone experience ensures that students integrate the KSA developed in the major and provides opportunities to develop the teamwork that will be such a large part of a rewarding professional life.

Stanford ME has chosen to retain accreditation, which provides a professional credential important to some of our students. Obviously, that professional role involves certain minimum standards, which go beyond the 100-unit cap currently proposed at Stanford, and the Committee's proposal does include an exemption for accredited degree programs. In many other Stanford Engineering departments, however, experience shows that students are less invested in an accredited degree. For them, the broader hallmarks of liberal education in a research university, like the more comprehensive ability to think well and to analyze multi-faceted problems successfully, dominate over the need for any specific professional credential. In those majors, the proposed 100-unit cap, which brings the total student effort demanded by the major down to nearly half of the overall requirement for graduation, may offer the more appropriate balance between specialist training and broad exploratory work. Offering some engineering majors that make relatively smaller demands will also help to ensure that engineering degrees, and the ways of thinking they provide, will remain accessible to all Stanford students even as variation in the preparation of our incoming students increases.

We offer this essay as an example of engineering education innovation at Stanford—historically, in modern times, and into the future. It aims to serve as a reminder to all of us that successful educational innovation needs to be aligned with larger institutional values and decision-making processes.

ACKNOWLEDGMENTS

We acknowledge the many faculty and students (past and present) at Stanford and beyond who have contributed to the ideas presented here. They have inspired us to revisit assumptions and consider new possibilities for building the Stanford education of the future. As such, this essay is dedicated to our future students. We are also grateful for the keen-eyed editing assistance provided by Ms. Tammy Liaw, the critical feedback from the paper review process, and the valuable suggestions from Designing Education Lab members (Abisola Kusimo, Barbara Karanian, Fred Krynen, Greses Gonzalez, Helen Chen, Joseph Towles, Lysander Homm, Madhurima Das, Nada Elfiki and Sonai Travaglini).

REFERENCES

ASME Board on Education, V2030 Project Group. 2012. *Vision 2030: Creating the Future of Mechanical Engineering Education.* Executive summary, ASME.

Jordan, David Starr. 1922. *The days of a man: being memories of a naturalist, teacher, and minor prophet of democracy.* Yonkers-on-Hudson: World Book Company.

Stanford University. 2014. "Handbooks." *Stanford Engineering Undergraduate Handbook.* Accessed 2020. https://stanford.app.box.com/s/1x4q39j5zb2gpv90e2ib7yu0i4m1mb7c.

Stanford University. 2019. *Report of the Design Team on the Future of the Major.* Stanford: Stanford University.

Stanford University. 1987. "The founding grant: with amendments, legislation, and court decrees." *Stanford Publications.* Accessed 2020. https://exhibits.stanford.edu/stanford-pubs/catalog/bz978md4965.

Stanford University. 2012. "The Report." *Study of Undergraduate Education at Stanford University.* Accessed 2020. https://sues.stanford.edu/report

AUTHORS

Sheri D. Sheppard is a Stanford professor of Mechanical Engineering. Besides teaching design-and mechanics related courses, she conducts research on how people become engineers. From 1999–2008 she was the Senior Scholar at the Carnegie Foundation for the Advancement of Teaching principally responsible for the Preparations for the Professions Program (PPP) engineering study, the results of which are contained in the report Educating Engineers: Designing for the Future of the Field. In addition, she served as Chair of Stanford's Faculty Senate in 2006–2007, and as Associate Vice Provost of Graduate Education from 2008–2013. In 2014 she was named U.S. Professor of the Year-Doctorial and Research Universities (CASE and the Carnegie Foundation for the Advancement of Teaching). Before coming to Stanford

University, she held several positions in the automotive industry, including senior research engineer at Ford Motor Company's Scientific Research Lab. Dr. Sheppard's graduate work was done at the University of Michigan.

R. Lanier Anderson (Professor of Philosophy, J.E. Wallace Sterling Professor in Humanities) works in the history of late modern philosophy and has focused primarily on Kant and his influence on nineteenth century philosophy. He is the author of *The Poverty of Conceptual Truth* (OUP, 2015) and many articles on Kant, Nietzsche, and the neo-Kantian movement. Current research interests include Kant's theoretical philosophy, Nietzsche's moral psychology, Montaigne, and special topics concerning existentialism and the relations between philosophy and literature (see, e.g., "Is Clarissa Dalloway Special?" *Philosophy and Literature*, 2017). He has been at Stanford since 1996, and has also taught at Harvard, Haverford, Bryn Mawr, and Penn. With Joshua Landy (Comparative Literature, French), he has been instrumental in Stanford's Philosophy and Literature Initiative. He currently serves Stanford as Senior Associate Dean for Humanities and Arts.

Thomas W. Kenny received the B.S. degree from the U of Minnesota, and the M.S. and Ph.D. degrees from UC Berkeley, all in physics. In 1994, he joined the Department of Mechanical Engineering, Stanford University, Stanford, CA, where he directs microsensor-based research in a variety of areas, including resonators, wafer-scale packaging, cantilever beam force sensors, microfluidics, and novel fabrication techniques for micromechanical structures. From 2006 to 2010, he served as a Program Manager at the Microsystems Technology Office at DARPA, starting and managing programs in thermal management, nanomanufacturing, manipulation of Casimir forces, and the Young Faculty Award. He is currently the Richard Weiland Professor of Mechanical Engineering and the Senior Associate Dean of Engineering for Student Affairs. He has authored or co-authored over 250 scientific papers and holds 50 issued patents, and has been primary Ph.D. advisor to over 70 graduated Ph.D. students from Stanford University.