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The Evolution of the Fulton Schools of Engineering: A Brief History, The Current Status, and Looking Forward to The Future

ANN F. MCKENNA

JAMES COLLOFELLO

AND

KYLE SQUIRES
Arizona State University
Tempe, Arizona

ABSTRACT

As part of being named one of ten emerging leaders in engineering education, Arizona State University (ASU) was invited to participate in the MIT-Olin Colloquium on the *Global State of the Art in Engineering Education* held in Boston in April 2019. As a group we shared innovations at our respective institutions and identified opportunities to collaborate to continue to advance the state of engineering education. In response to the guidelines for this special issue, this paper provides details on a few representative ASU achievements to date, and identifies opportunities for the continued evolution of the Fulton Schools of Engineering.

Key words: higher education, engineering curriculum, institutional change

INTRODUCTION AND ASU CONTEXT

Engineering education has been in a state of evolution for the past century. If we review the issues mentioned in the Mann report (1918), one of the earliest reports on engineering education, we see recurring themes today as described by several contemporary reports (e.g. National Academy of Engineering 2004, National Science Board 2007, National Academy of Engineering 2013, Graham 2018). As was the case in 1918 and throughout the 20th century, engineering education continues to confront a shortage of engineers, the demands of industry are shifting requiring engineering schools to adapt to the changing nature of the workforce, engineering curricula are crowded which presents challenges on how to integrate interdisciplinarity perspectives, there are debates on

effective pedagogical approaches to teaching engineering, there is a lack of diversity, and more (e.g. Wickenden 1930, Grinter 1955, Walker et al. 1968). Observing the evolution in engineering education over the past century, it is apparent that core issues have persisted, and while we have made substantive advances, there is much more to do.

Within the engineering education community there is growing commitment to understanding how to address issues from a systems-level, human-centered, partnership-based and global perspective. These are guiding principles we have applied within the Fulton Schools of Engineering (FSE) at ASU to develop and implement innovations in engineering education that leverage our place. We leverage our place by embracing the environment within which we reside including the socioeconomic and physical setting of Arizona, and by abiding by the mission of the institution to enhance local impact and social embeddedness. Another aspect of leveraging our place is the ASU charter which states that Arizona State University is a comprehensive public research university, measured not by whom we exclude, but rather by whom we include and how they succeed, advancing research and discovery of public value, and assuming fundamental responsibility for the economic, social, cultural and overall health of the communities it serves (ASU charter and goals, n.d.). Within the context of our place, we have a deliberate focus on the university's access mission which for our engineering education innovations requires that we approach all activities with a mindset to scale.

Motivated by an access mission that drives education at scale, ASU has worked to redefine the nature of a large public research university by taking a transformative approach that is guided by eight design aspirations (ASU design aspirations, n.d.)[1]. ASU's mission, charter, and design aspirations serve to create an environment and culture that demands thinking boldly, with an expectation to challenge the status quo. The context of ASU serves as an important backdrop for the efforts FSE has accomplished over the past 15 years. In response to the guidelines for this special issue, this paper provides details on a few representative FSE achievements to date. The intent is to provide examples that are specific to ASU, and that illustrate different features of the "system" of engineering education. The different features presented include 1) evolution of the organizational structure, 2) embedding student engagement at scale through the Fulton Difference, and 3) innovations in curriculum that embody universal learning at scale.

FSE ORGANIZATIONAL STRUCTURE

In 2003, what was then the ASU College of Engineering & Applied Sciences received a catalytic investment from Arizona-based land developer and philanthropist Ira A. Fulton. This investment – a

[1] The eight design aspirations of ASU are: leverage our place, enable student success, transform society, fuse intellectual disciplines, value entrepreneurship, be socially embedded, conduct use-inspired research, and engage globally.

$50 million endowment – sparked a reimagining of what an American engineering program should be. Inspired by the National Academy of Engineering (NAE) grand challenge themes, n.d. the college was restructured into five distinct and interdisciplinary units, collectively named the Ira A. Fulton Schools of Engineering:

- The School of Biological and Health Systems Engineering (SBHSE)
- The School of Computing, Informatics and Decision Systems Engineering (CIDSE)
- The School of Electrical, Computer and Energy Engineering (SECEE)
- The School for Engineering of Matter, Transport and Energy (SEMTE)
- The School of Sustainable Engineering and the Built Environment. (SSEBE)

A sixth school, The Polytechnic School (TPS), was added in 2014 as part of a merger with ASU's College of Technology and Innovation on the Polytechnic campus in Mesa, Arizona. Figure 1 provides a graphic overview of FSE's structure.

Within this new structure there are no formal departments, rather the academic unit is a school led by a school director. There are currently 25 undergraduate and 47 graduate degree programs within FSE and they reside within the schools based on alignment with the theme of the school. The reorganization had several aims, most notably to remove the silos that invariably exist between academic departments, to promote collaboration across the faculty, facilitate thinking about grand challenge problems from an interdisciplinary perspective, and to signal we are willing to challenge

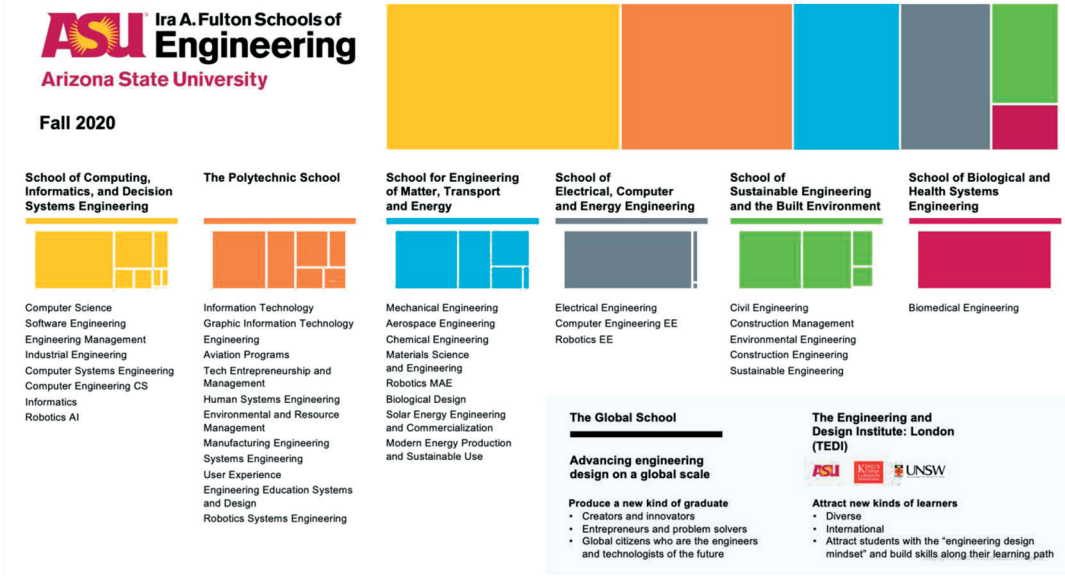

Figure 1. Organizational illustration of the Fulton Schools of Engineering at ASU.

the status quo in order to advance engineering education in a bold way. Another important feature of our structure is our transdisciplinary partnerships across the university where we share joint faculty hires, cobranded and cross college degree programs, research collaborations, and other entrepreneurial endeavors. Figure 1 also includes "The Global School" which is a new organizational unit that has recently been included to capture our educational activities that are globally focused. One specific activity that falls within the Global School is our partnership in launching The Engineering Design Institute (TEDI)-London, n.d. TEDI-London plans to admit its first students in Fall 2021 with the goal of providing a project-based, digitally enhanced, globally embedded, and student-driven approach to engineering education.

Since the reorganization, FSE enrollment has more than tripled over the last eight years to include nearly 25,000 undergraduate and graduate students. Concurrently we have added new degree and certificate programs including digitally immersed (online) degrees, expanded our industry partnerships for student project engagement, and developed student engagement and community building activities through the Fulton Difference—a term we use that encompasses the portfolio of activities offered to ensure student success. Enrollment growth in FSE online programs has increased 10x since 2012, and through innovations involving curriculum delivery and student engagement, we have succeeded in retaining close to 90% of our first-time first-year students into their sophomore year within the university. Moreover, our enrollment trends show that we are increasingly serving first generation students, transfer students, and veteran students. While these statistics are promising and trending positively, we also recognize opportunities for continued improvement in achieving learning outcomes, improving graduation rates, as well as increasing the overall diversity of the student population.

While the focus of this paper is on the education enterprise of FSE, it is relevant to note the research enterprise as well. Since 2014, FSE has increased research expenditures 40%, currently leads two National Science Foundation (NSF) Engineering Research Centers, and was responsible for nearly 150 patents and 21 startups in the last three years, placing ASU among the top four universities across the country for producing licenses, IP disclosures and startups. We view these metrics as additional indicators of success, in that ASU's access mission emphasizes the simultaneous pursuit of excellence, broad access to quality education and meaningful societal impact.

As we take a systems-view on these outcomes, the organizational structure is one variable that has contributed to achieving national prominence. However, within any organizational structure there are many interconnected components that interact to affect system outcomes. The Fulton Difference and curricular innovations are yet other variables within the system and examples of these components are described in the next sections.

THE FULTON DIFFERENCE

An overarching aim of our programs is to provide experiential, holistic, student engagement and community building activities to support student success and achievement – that we define as the "Fulton Difference." Our students are "engineers from day one" — part of a community of problem solvers, who are passionate about designing and making innovative and entrepreneurial solutions. Through the Fulton Difference there is a robust constellation of programs and activities that enable students to develop relationships with faculty and each other, feel part of a smaller community within FSE, develop professional skills that will enhance their careers as well as find the niche that satisfies their curiosity and interests. The Fulton Difference aligns with the eight ASU design aspirations and is based on the principles of: 1) focus on student success in the classroom and beyond, 2) accelerate use-inspired research and entrepreneurial engagement, 3) engage faculty dedicated to transforming engineering education, 4) engage stakeholders in industry and the community, and 5) make global impact. Below are descriptions of a few representative programs offered as part of the Fulton Difference.

EPICS

The Engineering Projects in Community Service program, known as EPICS Gold at ASU, is an award-winning community service and social entrepreneurship program. Through EPICS, students have the opportunity to obtain hands-on experience to problem solving while making an impact in the community.

E2 Camp Counselors (E2C2s)

E2 is an innovative program that welcomes all first-year students to our Fulton Schools of Engineering community. Upper-division students serve as counselors for this fun, multi-day, off-campus program. E2C2s help incoming students learn skills that are important to their success in FSE through a variety of interactive activities.

FURI (Fulton Undergraduate Research Initiative)

As a FURI researcher, students build a mentoring relationship with a faculty member outside of class. Through this paid engagement opportunity, students conduct research with a faculty mentor and present their findings at the semiannual FURI Symposium.

Grand Challenge Scholars Program (GCSP)

Students admitted to the Grand Challenge Scholars Program combine experiences in research, service learning, entrepreneurship and leadership, with the development of a global perspective

and interdisciplinary thinking. Grand Challenge Scholars receive a unique endorsement from the National Academy of Engineering upon completion of the program.

Peer Mentors

All first-year students—whether living in one of our residential communities, commuting to campus, or enrolled in our online programs—are assigned a peer mentor who provides referrals to academic resources across campus, hosts events to ensure new students feel connected to the Fulton Schools, and guides first-year students through the transition to ASU.

Undergraduate Teaching Assistants (UGTA)

The UGTA program hires successful undergraduate students to serve as teaching assistants in FSE classes. UGTAs assist faculty members by leading, engaging and mentoring students in exploratory and collaborative learning activities within the classroom and lab environment.

The above programs are just a few examples of how FSE provides opportunities for students to personalize and customize their experience. We believe that these programs help students develop a sense of belonging and that their path to professional success entails more than traditional course-work. The constellation of Fulton Difference experiential opportunities enables students to explore their interests, build confidence, hone skills such as leadership, teamwork, and public speaking, and prepare them for whatever career path they choose after graduation.

FSE CURRICULAR INNOVATIONS AND UNIVERSAL LEARNING

Consistent with ASU's vision for the broader university, our academic degree offerings align with the notion of "universal learning" which ASU describes as "evolving a model capable of being of service to all learners, at all stages of work and learning, from all socioeconomic backgrounds, through educational, training, and skill-building opportunities" (ASU Velocity of Change, n.d.). As we envision new programs, and refine and enhance current offerings we emphasize interdisciplinarity, societal impact, entrepreneurial mindset, and access. FSE has engaged in many different curricular innovations over the past 10 years, though for the sake of brevity, this paper will describe three specific activities: 1) online degree offerings, 2) earned admissions, and 3) the recently launched cross-school/college degree programs in robotics and autonomous systems.

Online Programs

FSE offers 12 undergraduate online degree programs and 14 online graduate degree programs, which we refer to as "digitally immersed delivery modes." From a universal learning perspective,

our digitally immersed programs afford access to engineering education to a wide demographic of learners. The average age of our online students is 30, 25% of online students are veterans, and 29% are first generation. These percentages exceed those in our campus-based programs, and indicate that online programs reach a non-traditional student demographic. The impressive growth (10X since 2012) also indicates that there is a societal need and demand for these types of programs.

Of the online programs, FSE's electrical engineering degree was the first in the nation to receive ABET accreditation. FSE also offers ABET accredited online programs in engineering management, information technology, and software engineering.

Earned Admissions

FSE participates in ASU's model of earned admission that allows students to gain admission to ASU by successfully completing a series of online courses that can count towards the degree. Through earned admission students can take the first-year engineering design course FSE 100 and the introduction to programming course CSE 110. The earned admissions program provides universal access to introductory engineering courses with a defined pathway for credit and admission to the university.

Robotics and Autonomous Systems

In response to emerging technologies and industry workforce needs, in 2018 we launched a new MS program that integrates topics related to robotics, artificial intelligence, autonomy, control systems, machine learning, and human-machine interaction in order to develop the next generation of intelligent robots. This program is not only an example of being agile and responsive to evolving technologies, it is illustrative of how our organizational structure allowed for ease of collaboration across disciplines. The program faculty are inclusive of four schools, and students can pursue specializations in four different areas by leveraging the range of expertise among the program faculty.

While we describe only a few specific examples of curricular approaches here, there are many other examples of educational innovations across FSE that embed project-based learning (e.g. Carberry and Brunhaver 2019, ElZomor et al. 2018, Gillespie 2019), instill an entrepreneurial mindset among engineering students (e.g. Huerta et al. 2019, London et al. 2018, Mayled et al. 2019) and develop an additive innovation and risk-taking mindset among the faculty (Abhyankar et al. 2019, Bekki et al. 2017). The examples mentioned here are just a few of the efforts that collectively contribute to the evolution of FSE's engineering education. Although we have many quality efforts underway, and have made great strides over the past decade, we recognize that there is more that we need to accomplish to be adaptable and to address longstanding and persistent issues facing engineering education.

LOOKING FORWARD—THE CONTINUED EVOLUTION OF FSE

As we reflect on our accomplishments, and the landscape of challenges and opportunities within engineering education, we have a strong sense of responsibility to continue to evolve FSE to meet the demands of the profession, the expectations and needs of students, and to contribute to the economic vitality of the communities we serve.

One of the foci as we move into the next phase of FSE's evolution is expansion of our global connections and degree offerings. Through our partnership with the PLuS Alliance n.d. we are developing new models for offering engineering degree programs on a global scale, and with a network of international partners as indicated by the TEDI-London initiative. These efforts will be informed by capacity-building engagements previously undertaken by FSE in Vietnam and Pakistan.

Our commitment to our communities and region will continue to provide key guidance to our evolution, consistent with the university charter that reinforces the importance of public universities to impact their place. As the nation's largest college of engineering and technology, we understand and embrace the opportunity to substantially advance the region's quality of life and especially the engineering and technology base of the Southwest and beyond.

Within FSE we also recognize an opportunity to reflect on how we can internally create a culture that is intentionally inclusive and equitable, whereby we provide meaningful pathways for achieving diversity. FSE was recently awarded Bronze Status by the ASEE Diversity Recognition Program, n.d. and we humbly view this recognition as one part of a holistic approach necessary to evolve and adapt our environment so that all who are part of it can thrive and succeed. These efforts present unique opportunities for leadership and to achieve significant impact given FSE's scale.

Consistent with the mission of ASU and its charter, FSE will continue on a trajectory of scale not just in terms of student enrollment but in the quality of our degree offerings, impact to society, and leadership in interdisciplinary research, discovery and development.

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AUTHORS

Ann F. McKenna is the Vice Dean of Strategic Advancement for the Ira A. Fulton Schools of Engineering at Arizona State University, and professor and director of the Polytechnic School, one of the six Fulton Schools. She was named one of the nine 2019 American Society for Engineering Education (ASEE) Fellows for demonstrating outstanding contributions to engineering education. Prior to joining ASU, she served as a program director at the National Science Foundation in the Division of Undergraduate Education, and was the director of education improvement in the McCormick School of Engineering at Northwestern University. McKenna received her bachelor's and master's degrees in mechanical engineering from Drexel University and doctorate from the University of California at Berkeley.

James Collofello serves as the vice dean of academic and student affairs and has held this position since 2006. In this capacity, he leads the school's student recruitment and retention, career development and placement, K-12 programming, new curriculum development, accreditation and oversight of Fulton Difference programming. Collofello is also a professor of computer science and software engineering. His teaching and research interests lie in the software engineering area with an emphasis on software project management and software quality assurance. Collofello received his bachelor's and master's degrees in mathematics from Northern Illinois University and doctorate in computer science from Northwestern University.

Kyle Squires serves as the dean for the Ira A. Fulton Schools of Engineering at Arizona State University. Previously, he served as the vice dean and interim dean for the Fulton Schools and as director of the School for Engineering of Matter, Transport and Energy (SEMTE), one of the six Ira A. Fulton Schools of Engineering. He has held numerous visiting appointments in the U.S., Japan and France and was elected a fellow of the American Physical Society in 2008. A professor of mechanical and aerospace engineering, Professor Squires' research expertise encompasses computational fluid dynamics, turbulence modeling of both single-phase and multi-phase flows, and high-performance computing. He received his bachelor's degree in mechanical engineering from Washington State University and master's and PhD from Stanford University.