The Modalities of Governance in Engineering Education

Dr. Atsushi Akera, Rensselaer Polytechnic Institute

Atsushi Akera is Associate Professor and Graduate Program Director in the Department of Science and Technology Studies at Rensselaer Polytechnic Institute (Troy, NY). He received his M.A. and Ph.D. in the History and Sociology of Science, University of Pennsylvania. His current research is on the history of engineering education reform in the United States (1945-present). He is a the current Chair of the ASEE Ad Hoc Committee on Interdivisional Cooperation; Chair of the International Network for Engineering Studies (INES); past chair of the ASEE Liberal Education / Engineering and Society Division; and a former member of the Society for the History of Technology's (SHOT) Executive Council. Publications include /Calculating a Natural World: Scientists, Engineers and Computers during the Rise of U.S. Cold War Research/ (MIT Press, 2006).

Dr. Soheil Fatehiboroujeni, Purdue University-Main Campus, West Lafayette (College of Engineering)

Soheil FatehiBoroujeni is a postdoctoral researcher at Purdue University School of Engineering Education as well as a lead instructor at Purdue First-Year Engineering Program. He received his Ph.D. in Mechanical Engineering from the University of California, Merced in 2018.

Sarah Appelhans, University at Albany-SUNY

Sarah Appelhans is a PhD candidate in Cultural Anthropology. Her dissertation research, "Steel Toes and Ponytails: Gender and Belonging in Engineering", investigates the boundaries of membership in engineering in the Capital District of New York. She is honored to be a research assistant on the NSF-sponsored study on engineering education reform entitled "The Distributed System of Governance in Engineering Education." In addition to her academic experience, she is a former mechanical engineer with several years of experience in the aviation and construction industries.

Dr. Alan Cheville, Bucknell University

Alan Cheville studied optoelectronics and ultrafast optics at Rice University, followed by 14 years as a faculty member at Oklahoma State University working on terahertz frequencies and engineering education. While at Oklahoma State, he developed courses in photonics and engineering design. After serving for two and a half years as a program director in engineering education at the National Science Foundation, he took a chair position in electrical engineering at Bucknell University. He is currently interested in engineering design education, engineering education policy, and the philosophy of engineering education.

Dr. Jennifer Karlin, Minnesota State University, Mankato

Jennifer Karlin spent the first half of her career at the South Dakota School of Mines and Technology, where she was a professor of industrial engineering and held the Pietz professorship for entrepreneurship and economic development. She is now a professor of integrated engineering at Minnesota State University, Mankato, where she is helping to build the Bell Engineering program, and the managing partner of Kaizen Academic.

Dr. Donna M Riley, Purdue University at West Lafayette

Donna Riley is Kamyar Haghighi Head of the School of Engineering Education and Professor of Engineering Education at Purdue University.

Dr. Thomas A De Pree, Bucknell University

Thomas De Pree is postdoctoral researcher at Bucknell University for the project, "Developing Human Social Networks to Identify and Develop Data-Driven Metrics and Methods for Expanding Learning Opportunities Across the Lifetime" (NSF, DUE-1745922), PI Alan Cheville and Co-PI Atsushi Akera. De Pree holds a Ph.D and M.S. in Science and Technology Studies (STS) from Rensselaer Polytechnic Institute in Troy, New York, and a M.A. in Anthropology and Education from Teachers College, Columbia University.

Rafael Julián Burgos-Mirabal, University of Massachusetts- Amherst

The Modalities of Governance in Engineering Education Reform

This paper is a work in progress of the second of two major reports that we expect to produce for a large-scale study of engineering education reform in the United States. It had been proposed as a poster session for the 2020 ASEE annual conference in Montreal, with the hope that this format would enable us to present preliminary findings to which we could secure the feedback of a broad community of engineering educators who comprise the membership of ASEE. Overall, our study is a multi-site, multi-scale investigation that utilizes semi-structured interviews to elicit new knowledge about the diverse social and organizational processes that inform, or govern, the development of new curricula, innovations, standards, and visions within engineering education. Examples of the phenomena we seek to understand include national initiatives such as the NAE Grand Challenges and ABET's Engineering Criterion 2000 (EC 2000), but we also attend to the multitude of local innovations responsive to student interests and local and national industrial needs. We have also sought understand the impact of state initiatives designed to control the costs of higher education, and the impact that this has had on engineering education. To date, we have assembled 286 interviews from over 40 colleges and universities, a half dozen engineering professional organizations, and individual educators, with an additional 27 student interviews designed to verify certain findings from our faculty and institutional data set. It is our goal to understand the social and organizational processes that determine how changes in engineering education occur, and understand this well enough to present policy recommendations on how to pursue effective, meaningful, and enduring changes in engineering education at different institutional scales.

Our first major work-in-progress report was presented last year at ASEE 2019 in Tampa, Florida and was on the development and implementation of ABET EC 2000 [1]. While ABET is a major part of what drives change in engineering education, we do not address accreditation directly in this paper. Instead, this year we focus on the broader social and organizational processes associated with "higher education governance" and their specific manifestation within engineering education. Our work is informed in part by Austin & Jones' *The Governance of Higher Education* [2], a book-length review of a diverse body of scholarship spanning multiple disciplines that speaks to the different social and organizational processes that exist for directing our diverse systems of higher education. However, rather than relying exclusively on established theoretical frameworks we made use of grounded theory methods [3] to elicit, through our interviews, a wide range of comments about more ordinary, local, and diffuse processes that can be found within the general arena of engineering education reform. During the poster session, and in the paper that follows, we present the ASEE community with a survey of these different modalities of governance, which we define as any recognizable institutional arrangement or process that has an influence on the structure and content of engineering education. We also use

this paper to open up a conversation about the policy implications that follow from these observations.

As a work in progress, the paper that follows limits itself to a general description of the content we expect to present during our poster session, with a focus on mapping out the nine modalities of governance that emerged most prominently in our data. More detailed empirical findings will be presented during the poster session and integrated into a subsequent publication. In what follows, the implications of our work will be worded so as to open up a policy dialogue, rather than attempting to deliver comprehensive policy recommendations. We expect a wider range of policy options to emerge as a result of our conversation with the ASEE membership during the poster session, and through feedback on more developed versions of this manuscript.

Background, Analytic Framework, and Method

Systematic descriptions of US engineering education have been elusive because of the incredible diversity of US institutional arrangements for delivering engineering education, a diversity compounded by the decentralized structure of the engineering profession and the dynamic nature of engineering education itself. It has been demonstrated by Ken Alder [4] that even in state-dominated systems of engineering education, engineering education has always been served by different kinds of educational institutions. While this is also true with regards to the United States, engineering education in the U.S. is especially diverse because it is offered by both public and private institutions, and at general universities, dedicated engineering schools, embedded programs at liberal arts colleges, and partially through a diverse national network of community colleges. These institutions are also governed by more than fifty different state systems of higher education, influenced by professional societies other engineering professional organizations, and shaped by the large volume of federal research expenditures. Technological change, industrial demands, and regional differences also are significant factors. Meanwhile, although sociologists of the occupations have long ago abandoned the idea of medicine and law as being ideal-typical professions [5], the unique configuration of the engineering profession, with its more substantial fragmentation by sub-discipline, permeable boundary between engineering and management, relation to industrial geography and structure, and more limited and varied relationship with the state ensure that a description of this system, let alone control of it, remains a difficult if not impossible endeavor [6-8].

That said, any system, however loosely coupled, is subject to some degree of control and characterization; we set out here to document what that control looks like. In part, we rely on the theoretical frameworks introduced by Austin and Jones [2]—institutionalism, resource dependency theory, stewardship theory, and others—as an important means of identifying modalities of governance that are known to exist within the realm of higher education and have direct influence on engineering education. That said, our multi-site and multi-scale research

design directs our collective attention to other institutional arrangements and organizational processes that may be less familiar to scholars of higher education governance and may apply more uniquely to engineering education [9, 10]. In their final form, our semi-structured interview questions designed to elicit information about these diverse modalities of governance that operate are described in Table 1, below.

Table 1: Semi-Structured Interview Questions
(in abridged form; includes additional questions as related, for example, to demographics)

1. What is your name, age, race, ethnicity and/or nationality, and current position?
2. Could you tell us about the history of your institution?
3. Can you tell us your personal history, and how you became involved with engineering education?
4. What do you consider to be the greatest challenges in higher education and engineering education?
5. What are the biggest challenges that your institution currently face? What major initiatives have there been in response?
6. Could you describe your major curricular and pedagogic initiatives? New facilities or initiatives in teaching that have been made?
7. We're interested in understanding the process of educational reform. With regards to any one initiative you've been involved with, what did it take to get the initiative off the ground, and what did it take to implement it?
8. Tell us something about your students.
9. What approach does your institution take towards diversity and inclusion, and are they effective?
10. What external organizations influence your academic programs?
11. What is your general approach to accreditation? What experiences have you had?
12. Tell us about the sponsored research side of your university (and/or your university's commitment to research), and how it affects engineering education at your institution.
13. What will your program and institution look like 10 and 25 years from now?

Our site and subject selection were driven by a selection matrix to ensure diverse representation in our data set. The overall institutional makeup of our assembled data is as depicted in Table 2 (reduced here to a table to limit identification).

Table 2: Sample Demographics

	N=
Overall Sample	
Colleges & universities (4-year institutions)	
Full participation (4+ interviews)	26
1-3 interviews only	11
Community colleges (2-year institutions)	5
Engineering professional/education organization	6
Individual educators & researchers	13
Student Interviews	27

Institutional Demographics of Colleges & Universities Full participating institutions only (N=26)	
By Tier (US News & World Report, undergrad engg. rankings)	
Doctorate granting #1-#10	6
Non-doctorate granting #1-#10	5
Either category #11-#30	8
Either, #75+ doctorate, #40+ non-doctorate	7
Geographic location	
East coast	7
South	6
West	6
Midwest	7
Institutional type	
Public universities	11
Private universities	2
Public engineering schools	3
Private engineering schools	6
Liberal arts colleges (with embedded programs)	4
Minority and women serving institutions (Would also be one of the above.)	5

In order to understand change processes within an organization, our multi-scale research design called for interviewing educators in different positions within an organization, ranging from the dean of engineering and provost (or a member of the provost's office), to department heads, senior and junior faculty members, lecturers, and staff or faculty advisors. For the university interviews, our overall response rate was 72% (N=26/36), with 56% (N=20/36) complying with our request to schedule either the full range of interview subjects, or a significant portion thereof ("full participation" in Table 2 above). For our visits, we invited institutions to recommend individuals who they felt were pursuing innovative changes at their institution. While this allowed us to gain greater access and insight into change processes that the institutions themselves deemed most important, it is necessary throughout this paper to recognize this inherent sample bias. The student interviews are described in a separate paper at this conference [11]. We used MAXQDA, a qualitative data analysis software similar to NVivo and ATLAS.ti, for data analysis.

Major Modalities of Governance in US Engineering Education

So far, we have completed our "first-pass" coding effort, which consisted of reviewing the 211 approved transcripts that had been loaded into MAXQDA and classifying relevant passages according to 264 emergent codes (vs. pre-determined codes) that pertained to phenomena of possible interest. While by no means a comprehensive list, the following modalities of governance stood out in our initial analysis to be the most salient features of the US system of engineering education. While this heterogeneous list is presented in no specific order, structural features dominate the beginning of the list, while features that emphasize local actors and agency

dominate the latter part of the list. Many of the different modalities also exist in a metonymic relation to one another, or exist in tension and sometimes conflict.

1. Engineering education is a complex, dynamic, open system with extensive local variation

At the broadest level, engineering education in the United States operates as a highly complex, dynamic, open system with extensive local variation.[1] The dynamic nature of the system can in large measure be attributed to the fact that engineering knowledge is commonly regarded as instrumental knowledge [12]. While much can be said about what this knowledge is instrumental for, this professional ownership of a sense of societal relevance leads to a shared understanding that engineering educators should always strive to adapt their knowledge to "changing times and needs." The response, however, varies according to each educator's views with regards to the social purpose of engineering and the responsibilities of their profession. Engineering education in the US also operates within and is itself a highly complex institutional ecology owing to the structure of US higher education and the structure of the engineering profession, contributing to tremendous variation in local initiatives and actions.[2] This makes the governance of engineering education, whether with regards to standards, or the development of a new, unified educational vision, highly difficult. Engineering education in fact operates as a complex, higher order system made up of many complex parts, some of which are tightly coupled, but large parts of which remain loosely coordinated at best. There are self-organizing properties built around professional and disciplinary interests, as exemplified by the difference between civil engineering and other engineering disciplines with regards to curricula and licensure. That said, the high degree of variation at system level results from a lack of coordination and the lack of a single professional vision. It is also the product of an epistemic commitment to innovation as discussed below.

Policy implications: Engineering educators and administrators need to be aware of the complexity of the institutional contexts within which they operate, and develop solutions adapted

---

[1] Though there are elements of engineering education that appear to be obdurate structures at the broader scales of analysis (e.g. organizations), and these are obdurate in the sense that they often appear difficult to control and difficult to change, with a finer-grain analysis we can begin to unpack how agency—the capacity to bring about change—is distributed throughout the system. Thus, as we move from the macro-scale to the mezzo- and micro-scale, we begin to see how even the most structural elements—state education bureaucracies for instance—are both enacted and constantly altered through a vast network of ordinary everyday actions, widely distributed throughout the system in ways that enact change… or reinforce what is already given. We explore this in our discussion of the other modes of governance, below.

[2] The notion of institutional ecology goes back to C. Everett Hughes [13], symbolic interactionists, and the theories advanced by the Chicago School of Sociology. Within the history and sociology of science, derivative ideas about the ecology of knowledge and its organizational implications may be found in the works of Charles Rosenberg [14] and Susan Leigh Star [15]. See also [16].

to their specific situation. Given the absence of a unified professional vision, engineering educators may also need to remain cognizant of the moral and ethical dimensions of their work, and pursue change initiatives aligned with the needs of their own student body, and other locally defined interests.

2. The Epistemic culture[3] of engineers, and how this influences their educational reforms

If the epistemic culture of science is built around discovery, the epistemic culture of engineering is built around invention and innovation. While it may be difficult to see what is right under our noses, engineering educators approach engineering education with the same epistemic commitment to "innovation" that they pursue in their professional practice. We see the phrase repeatedly in our data. Engineering educators therefore view it as their professional duty to develop innovative curricula, instructional programs, pedagogy, educational facilities, and educational technologies. This constant push towards innovation can frustrate efforts to coordinate and standardize educational content and processes, but it also fuels the widely diffused effort to pursue incremental improvements, often in the name of educational efficiency. Other epistemic commitments, such as risk aversion and a preference for quantitative assessments have been reported by Seron and Silbey [18] and is verified by our data in many ways that go beyond their commentary on accreditation standards. (Again, detailed data will be presented during the poster session.) Occasionally, we see instances where the epistemic culture and practice of engineers, such as the use of flow diagrams to map curricular dependency, has more extensive influence on specific reform initiatives undertaken by a particular institution or department.

Policy implications: We need to attend to our own habits as engineers and make sure they remain aligned with our overall goals, as opposed to pursuing intermediary objectives that result from the methods engineers know to employ. While the engineering educators' capacity to develop new curricula and new approaches to engineering education are an asset, the organizational capacity to understand, recognize, and reign in innovation so that we are able to develop meaningful educational standards and to provide some needed stability probably needs to be developed at every level of our academic organizations. This may be an important factor in the effective diffusion of the most successful initiatives and practices.

3. Bureaucratic structures and ordinary everyday actions

---

[3] The epistemic culture of any discipline is the entire assemblage of the theories about knowledge, tools, instruments and technologies, and material practices characteristic of the discipline. Epistemic cultures are not necessarily monolithic, but are internally consistent enough to stand to description. For a classic discussion of epistemic cultures, as applied to science (specifically physics and molecular biology), see Karin Knorr-Cetina's *Epistemic Cultures* [17].

While engineering educators may place a somewhat unique emphasis on innovation, the most common practices of educational reform within engineering education arise out of normal bureaucratic processes that are defined within and across academic organizations. As suggested by those who work within the ethnomethodological tradition [19-21], such processes are exercised through what they refer to as "ordinary everyday actions." From curriculum committees and industrial advisory committees; to ABET's Board of Delegates, commissions, committees, and task-forces; to NSF program officers and peer review panels, all of the different bodies within engineering education operate through both explicit and tacit rules of procedure. While some procedures are significantly codified, others are more loosely defined, opening the way to creativity and improvisation in organizational conduct. The coexistence of many different professional organizations with an influence on engineering education also guarantees that change can originate from different directions. Thus, although Austin and Jones identify a number of higher order phenomena, such as academic entrepreneurialism, resource dependence, and institutional stewardship which we also see, our data suggests that these other, ordinary bureaucratic processes do as much to determine how educational innovation and changes unfold at each of the institutions we studied.

Policy implications: Educational change processes are skilled performances grounded in bureaucratic organizations and their rules of procedure. Skilled acts of organizational innovation and improvisation designed to forge new institutional arrangements are an important part of what makes engineering education in the U.S. dynamic. No less than the US Senators who know how to manipulate rules of procedure to shape political outcomes, educational change requires skilled actors that are effective at mobilizing both ordinary and extraordinary processes for initiating and managing change. Efforts to cultivate leadership by creating skilled organizational actors should be built into every academic organization, with an explicit eye towards effectively managing change processes. Even at research universities, "service" may need to be recognized more explicitly as a parallel category to "research," rather than an add-on, if the cultivation and recognition of leadership is a goal.

4. **Neoliberal modes of governance**

Consistent with one of Austin and Jones' findings, our data point to a substantial expansion in neoliberal modes of governance, especially within public institutions of higher education. At state level, higher education bureaucracies stand as a check against legislative influence, but state legislatures have embraced neoliberal modes of governance to reshape the U.S. higher education landscape, most notably through increased use of accountability-based metrics and assessment. This has introduced a greater degree of "market-like" behavior in US higher education, although not without eclectic features that differentiate it from a true (liberal) market. Indeed, the implementation of these systems vary greatly, state by state, with state and state systems possessing strong, independent governance entities—the University of California's Board of

Regents, for example—better positioned to limit the impact of neoliberal expansion. Conversely, in a state like Florida, where there is no real state system of higher education, performance metrics and institutional competition have permeated deeply into the conduct of academic organizations. Their effects can be seen operating at faculty level, although public funding remains a highly political process in that state.

Unfortunately, the expansion of performance-based metrics has had a disproportionate impact on engineering education because many of the measures designed to determine allocations, such as four year graduation rates, are not compatible with engineering education's math-science heavy curricula. The related issue of retention, as compounded by increasingly diverse student bodies and their diverse preparation, also frustrate engineering educators' efforts to meet state targets. Accountability based metrics have also entered engineering education through other channels, most notably the rise of outcomes assessment as a result of the ABET Engineering Criterion 2000 reforms, which we have written about separately [1].

Policy implications: While there may be reasons for utilizing performance metrics to control the costs of higher education and to enhance our capacity for continuous improvement [1], our data suggest that these systems are not always efficient. States may have other priorities, such as STEM workforce development, that are undermined by the systems they themselves have put in place. States that rely on performance metrics should make sure that they develop a real capacity to listen to universities and their engineering faculty about the impacts of proposed policy changes so these changes can be more effectively aligned to the state's own policy priorities.

5. National rankings and the educational marketplace

National ranking systems, and especially US News and World Reports, has become a major fixture within US higher education. While many of those whom we interviewed insist that such rankings are irrelevant to how and what they teach, our data suggests that even at the highest ranked institutions, there are those within each college or university whose decisions and conduct are deeply shaped by these rankings. Like any market or market-like mechanism, rankings serve to coordinate educational institutions by creating a single, if still substantially differentiated higher education market. The prevalence of these rankings in the public mind have prompted many universities to strengthen their enrollment management strategies in order to expand enrollments, maintain better balance across enrollment swings, and to manage their discount rates (amounts offered through financial aid) to keep their institutions solvent—a pressure that is likely only to intensify due to the fiscal impacts of the current COVID-19 pandemic. Many institutions report that the downside of national rankings is that they do not accurately reflect the quality of education offered by their institution, and therefore do not make for an efficient market. Indeed, our data point to specific gaming behaviors, often tuned to the algorithms employed by US News and World Reports, resulting in skewed resource allocations [22]. While the "business" of higher education operates under the logic of capitalism, the increased emphasis

on fiscally-motivated competition can also compromise the other goals of higher education, including the social, moral, and personal development of our students.

Policy implications: So long as national rankings capture the imagination of high school students and their parents—or even just the administrators who imagine this influence to exist—the phenomena described above will be difficult to avoid. While it may be an option for some institutions to deemphasize or decenter rankings in their recruiting strategies, it remains important for all academic administrators to remain vigilant about not allowing their engagement with national rankings to compromise the quality of their academic programs. Our data on the nature of this competition suggests that colleges and universities, acting through specific engineering education and professional organizations, can continue to work with USNWR to make meaningful refinements to the ranking algorithms; alternative ranking systems managed by those with greater knowledge of engineering education might also be a possibility.

6. Other modalities of coordination

There are other modes of coordination that operate at a more local level. Industrial advisory committees, department heads' associations and organizations, the ABET Board of Delegates, and other entities exist throughout the system of engineering education in ways that enable conversations to occur across organizations. When successful, these mechanisms for coordination realign engineering education and most frequently its curricula to meet ever changing socioeconomic, technical, and industrial contexts and the associated state and regional STEM workforce needs. Because of the distributed structure of the engineering profession and its educational institutions, broad coordination at the highest level, beyond the market-like mechanism provided by USNWR, occurs only during moments of national crisis when there is a perceived, major misalignment between the prevailing educational system and the dominant needs of society. Through separate historical work, we have ascertained how a focus on "humanistic-social" education as a result of the Great Depression and World War II, and the rise of engineering science during the early Cold War years can be attributed to reform initiatives that achieved this level of coordination because of a national crisis [23]. While there was in the past a well-defined body of practice for achieving such coordination in engineering education, namely the grand investigative tradition of ASEE that produced the Wickenden Investigations (1930, 1934) [24]; the Grinter Report (1955) [25], and the Goals Report (1968) [26], the collapse of this tradition during the late 1960s forced engineering educators to turn to more ad hoc processes as was found during the development of EC 2000 [1]; or else to policy statements and changes that have been limited to the organizational reach of a single coordinating entity (e.g. NAE's Engineer of 2020 [27] and ASME's Vision 2030 [28]).

Policy implications: If a coordinated response is deemed important for the engineering profession to effectively serve national priorities, engineering educators should consider the

merits of working to rebuild the capacity for some organization to serve as the "voice of engineering education," a role that ASEE has played in the past. We might also leverage the diversity of US engineering education, promoting more local coordination among, for instance, state universities serving students with diverse backgrounds. That said, it appears that every engineering professional organization and academic organization should remain cognizant of the complexity of the educational ecosystem and always strive to involve stakeholders that lay beyond the boundaries of their own organization.

7. Faculty autonomy and their domains of responsibility

A very important strength of the US system of engineering education rests with the autonomy of its faculty, the overall strength of their research profile, and their capacity to bring new innovations to engineering education. While individually engineering faculty, especially at R1 institutions, do not always prioritize teaching, without exception every engineering school we visited had a group of committed educators for whom teaching was a major reason for being in academe. The energy and commitment that these faculty devote to teaching is truly inspiring, and is in no way eclipsed by the devotion to teaching found in other disciplines.

This said, challenges do remain. At the departmental level, our data repeatedly show that faculty investments in their current teaching often produce curricular stagnation and gridlock. Continuous improvement processes remain uneven, and are not always aligned with ABET processes [1]. Each institution's capacity to respond to evolving student interests and demands, such as the recent surge of the interest in computer science, data science, and AI, varies greatly. New interdisciplinary undergraduate programs spanning multiple academic departments have sometimes been set up in ways that have eroded the faculty's ownership and authority over curricula.

Policy implications: As already noted earlier, faculty should resist the temptation to always invent something new, and focus at times on the value of careful deliberation about successful practices elsewhere, with regards to instructional methods as well as curricula. Greater attention should be paid to educational research. While the dynamics of the educational market make it necessary to follow student interests and employers, faculty and administrators should remain vigilant about educational goals and the sustainability of new educational programs they create. This said, new programs that explicitly support the needs, capacity, and interests of the diverse body of students that we are now admitting needs to be expanded.

8. The impact of engineering education research

Data driven approaches to education are contiguous with the epistemic culture of engineering. While educational research has been a feature of engineering education at least since the late

1960s, public frustration with educational outcomes, the perceived if not actual neglect of undergraduates, and the rise of targeted funding strategies at NSF (and the attendant need to justify their investments) has brought an increased focus on educational research. The shift towards outcomes assessment brought about by EC 2000, neoliberal interest in measurement and accountability, and changes in the *Journal of Engineering Education's* editorial policies have also contributed to the substantial expansion of engineering education research.

However, our data make it clear that most engineering educators and administrators still do not follow the educational research literature, except indirectly through colleagues they have hired for their knowledge and activities in the field. A culture of extensive reading simply is not a part of engineering practice, even by academic engineers. This does not mean that educational research has not impacted engineering education; increasingly, when major educational initiatives are proposed, especially in areas such as diversity and inclusion, those with a background in educational research are brought in to give shape those initiatives. There are many other activities and areas, such as project-based learning, women in engineering, effective group work, and oral and written communication that have been broadly influenced by the literature. While there has been a shift towards accepting qualitative and mixed-mode analyses, broad gauge studies, such as ours, remain rare. NSF programs such as Research Initiation in Educational Formation (REIF), and NSF funding in general have served to expand our capacity for educational research and for bringing new engineering educators into the fold.

Policy implications: While engineering education research has established itself as a significant driver for changes in engineering education, there nevertheless remains a real gap between research and practice. Those engaged in engineering education research must attend to the effective dissemination of their ideas, and academic administrators everywhere needs to develop their local, organizational capacity to incorporate such research into the instructional and organizational practices of their faculty. This should continue to occur in ways that are cognizant of local conditions, diverse student populations, and different needs.

9. Students as drivers

Finally students are not an insignificant factor when it comes to change in engineering education. While U.S. secondary schools have expanded their STEM education programs, and colleges their outreach activities, they've done so through hands-on activities because of a primary emphasis on recruitment. However, most engineering educators, and not just those at research universities, remain wedded to science-based curricula, producing the phenomenon of "bait and switch" described by Lachney and Nieusma [29]. As our other paper in this conference shows, this is often confusing and off-putting to students, and contributes quite directly to the retention problem in our field. Fiscal pressures, national rankings, and increased competition for students has only exacerbated the problem. Increasingly, students have been voting with their feet,

compounding the retention problem. While schools have built maker spaces, organized entrepreneurship programs, and ramped up their focus on internships, co-ops, and undergraduate research, any initiative that is not fully integrated with the academic goals of the faculty poses the risk that students will invest their time in activities that compete for their time and attention.

Policy implications: Our data suggest that undergraduate (non-PhD granting) institutions tend to do better than R1 institutions in addressing student interests when making changes to their curricula and educational offerings. Their curriculum development and pedagogic improvement processes might serve as a model for other institutions, although their specific initiatives might be more suited to local conditions. While programs should remain responsive to student interests, careful thought should be given to academic objectives and the value of supporting diverse student pathways in ways that go beyond recruitment and retention.

Conclusion

This is not, by any means, a comprehensive list of the forces at work in reshaping engineering education today. Still, the nine modalities of governance described above emerged as the dominant features of what drives engineering education reform in the U.S., based on the initial coding of our interview data. As noted at the outset, our list offers a general progression from more "structural" modalities of governance (markets, professional structure, bureaucratic processes) towards those focused on the distributed agency of individuals and organizations (faculty, researchers, students, acting individually and in organized units). These are clearly two faces of the same coin—the "dualism" versus "duality" in Anthony Giddens' structuration theory [30]—suggesting that we need to view these modalities of governance as operating simultaneously, and sometimes in tension. This is compatible with the ecological and systems oriented perspective from which we chose to study engineering education governance. Given that this is a work in progress, where we seek to develop our ideas in dialogue with our audience, we will close the paper with these sparse concluding remarks. We welcome all those who read this paper to send us your thoughts (and any case studies that you are willing to share with us) by emailing any of the authors starting with the project PIs: akeraa@rpi.edu, rac039@rpi.edu, riley@purdue.edu.

References

[1] Akera, A., Appelhans, S., Cheville, A., De Pree, T., Fatehiboroujeni, S., Karlin, J., Riley, D. M., ABET & engineering accreditation - history, theory, practice: initial findings from a national study on the governance of engineering education, in *Proceedings of the 2019 ASEE Annual Conference & Exposition,* Tampa, Fla., June 2019.

[2] Austin, I., Jones, G., *Governance of higher education*. New York: Routledge, 2016.

[3] Corbin, J. M. & Strauss, A, *Basics of qualitative research: techniques and procedures for developing grounded theory,* 3rd edition. Thousand Oaks, Calif.: Sage Publications, 2008.

[4] Alder, K., *Engineering the revolution: arms and Enlightenment in France, 1763-1815.* Princeton, NJ: Princeton University Press, 1997.

[5] Larson, M., *The rise of professionalism: a sociological analysis,* Berkeley, Calif.: University of California Press, 1977.

[6] Layton, E., *Revolt of the engineers: social responsibility and the American engineering profession,* Baltimore: Johns Hopkins University Press, 1986.

[7] Noble, D., *America by design: science, technology, and the rise of US corporate capitalism,* New York: Knopf, 1977.

[8] Wisnioski, M., *Engineers for change: competing visions of technology in 1960s America,* Cambridge, Mass.: MIT Press, 2012.

[9] Marcus, G., Ethnography in/of World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Anthropology*, 24 (1995):95-117.

[10] Fortun, K., Scaling and Visualizing Multi-sited Ethnography, in *Multi-sited ethnography: theory, praxis and locality in contemporary research*, Mark-Anthony Falzon (Ed.), U.K.: Ashgate, 2009.

[11] Akera A., Fatehiboroujeni, S., Appelhans, S., Aviles, J., Debong, E. Mendiola, B., Murray, M., Shuey, M., Tsyndra, M., Wahaus, M., Student perspectives on navigating engineering pathways, *Proceedings of the ASEE Annual Conference and Exposition,* Montreal, Canada, June 2020.

[12] Akera, A., *Calculating a natural world: Scientists, engineers, and computers during the rise of U.S. Cold War research*, Cambridge, Mass.: The MIT Press, 2006.

[13] Hughes, C. E., Ecological aspect of institutions, in *The sociological eye: selected papers,* Chicago: Aldine-Atherton, 1971, pp. 5-13.

[14] Rosenberg, C., Toward an ecology of knowledge: on discipline, context, and history, in *No other gods: on science and American social thought,* Baltimore: Johns Hopkins University Press, 1976, pp. 225-239.

[15] Star, S. L., (ed.), *Ecologies of knowledge: work and politics in science and technology,* Albany: State University of New York Press, 1995.

[16] Akera, A., Constructing a representation of an ecology of knowledge, *Social Studies of Science,* 37/3 (2007): 413-441.

[17] Knorr Cetina, K., *Epistemic cultures: How the sciences make knowledge,* Cambridge, Mass.: Harvard University press, 1999.

[18] Seron, C. & Silbey, S., The dialectic between expert knowledge and professional discretion: accreditation, social control and the limits of instrumental logic, *Engineering Studies,* 1/2 (2009): 101-127.

[19] Garfinkel, H., *Studies in ethnomethodology,* Englewood Cliffs: N.J.: Prentice-Hall, 1967.

[20] Garfinkel, H. (ed.), *Ethnomethodological studies of work,* London: Routledge and Kegan Paul, 1986.

[21] Lynch, M., *Scientific practice and ordinary action: ethnomethodology and the social studies of science,* London: Cambridge University Press, 1994.

[22] O'Neil, C., *Weapons of math destruction: How big data increases inequality and threatens democracy,* New York, N.Y.: Crown Publishing Group, 2016.

[23] Akera, A. Setting the standards for engineering education: a history, *Proceedings of the IEEE,* 105/9 (September 2017), 1834-1843.

[24] Society for the Promotion of Engineering Education (SPEE). *Report of the investigation of engineering education, 1923-1929*, [Wickenden investigations], 2 vols., Pittsburgh: Society for the Promotion of Engineering Education, 1930, 1934.

[25] American Society for Engineering Education (ASEE), *The report of the Committee on Evaluation of Engineering Education*, [Grinter Report], Washington D.C.: ASEE, 1955.

[26] American Society for Engineering Education (ASEE), *Final Report: Goals of Engineering Education*, Washington, D.C.: ASEE, Jan. 1968.

[27] National Academy of Engineering (NAE), *The Engineer of 2020: Visions of Engineering in the New Century.* Washington D.C.: National Academies Press, 2004.

[28] ASME, *Vision 2030: creating the future of mechanical engineering education.* Phase 1 Final Report, Center for Education, December 2011. https://community.asme.org/board_education/m/mediagallery/4489/download.aspx (Accessed 2/3/2020).

[29] Lachney, M., & Nieusma, D., Engineering bait-and-switch: K-12 recruitment strategies meet university curricula and culture, in *Proceedings of the 2015 ASEE Annual Conference & Exposition,* Seattle, Wash., June 2015.

[30] Giddens, A., *The constitution of society: outline of a theory of structuration,* Berkeley, Calif.: University of California Press, 1984.