2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33256

Visions of Engineers for the Future: A Comparison of American and Chinese Policy Discourses on Engineering Education Innovation

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Abstract

The US National Academy of Engineering reports *The Engineer of 2020* and *Educating the Engineer of 2020* marked an important shift in policy thinking regarding engineering education: the emphasis of engineering education leaders thence shifted from producing engineers based on existing socioeconomic demands to actively envisioning and shaping the roles and characteristics of engineers in the future. Writing in the year of 2020, when engineering education yet again faces looming paradigm shift driven in part by a global pandemic and major powers' adjustment in attitudes and strategies to globalization, we attempt to reassess visions of "engineers for the future," as reflected through policy discourses in the United States and China, two major players in global engineering education. For this purpose, we present a careful reading of recent policy documents published by the US National Academy of Engineering (NAE) and the Chinese Ministry of Education (MoE).

The NAE (2018) report *Understanding the Educational and Career Pathways of Engineers* resulted from a study commissioned by the Academy to "understand characteristics and career choices of engineering graduates, … as well as the characteristics of those with non-engineering degrees who are employed as engineers in the United States." Authors of the report sought to sustain the supply of competent engineers in the US by investigating "the engineering education-to-workforce pathway." Around the same time that the NAE study was conducted, engineering educators and policy makers in China were engaged in a series of conversations aimed at renewing China's engineering education for the next thirty years. These conversations laid the groundwork for the Emerging Engineering Education (3E) initiative, announced officially by the MoE in 2017 and followed by waves of funded engineering education research and practice projects across the nation.

This paper examines and compares the visions of "engineers for the future" embodied in the NAE (2018) report and the 3E initiative (2017) in China. Our analysis of policy texts seeks to answer the following questions: What assessment of engineering education reality in the US and in China respectively motivated the NAE study and the 3E initiative? What visions of engineers and engineering education are advanced in the respective policy documents? Accordingly, what changes in engineering education are recommended for meeting the visions proposed by policy scholars in the US and China?

Answering these questions will help us engage critically in discourses about the future of engineers and engineering education from a transnational perspective. Perhaps through conversations involving the global community of engineering educators, we might aspire to a broader and more inclusive vision of global engineering education than NAE and MoE has each aspired to accomplish in its own national context.

Introduction

> *"With the prospect of the exciting new developments expected to come from such fields as biotechnology, nanotechnology, and high-performance computing, the year 2020 can be a time of new choices and opportunities. The years between the present and 2020 offer engineering the opportunity to strengthen its leadership role in society and to define an engineering career as one of the most influential and valuable in society and one that is attractive for the best and the brightest."*—National Academy of Engineering, "The Engineer of 2020" [1].

A series of reports throughout the latter decades of the 20th Century criticized STEM education in the United States for failing to meet demands to remain globally competitive [2]. Such calls increased in urgency as a series of technologically advancing events of the mid-1990s leveled the global playing field in economic and technological leadership – a leveling that authors such as Thomas Friedman described as a "Flat World" [3-6]. Looking toward this more competitive, interconnected future, particularly with new developments in the STEM education and workforce in China and India, in 2004 the U.S. National Academy of Engineering outlined a strategy in a report entitled *The Engineer of 2020: Visions of Engineering in the New Century* [1] that described the characteristics and skills that would be required of graduating engineering students for the U.S. to compete successfully in the "flat world" of 2020. In creating a list of attributes, the report's authors assumed that: 1) technological innovation will continue to expand rapidly, 2) the interconnectedness of the world will become denser, 3) wider swaths and more diverse segments of the population will be influenced by innovations, and 4) social, cultural, political, and economic forces will determine whether innovations and engineering solutions are successful to an even greater extent. The report asserted that engineering programs should strive to produce graduates ready to succeed in this workforce of the future, and graduates should possess the following attributes: strong analytical skills; practical ingenuity; creativity; communication; business management and leadership; high ethical standards with a strong sense of professionalism; dynamism, agility, resilience, flexibility, and lifelong learning. A follow-up report in 2005, entitled *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, recommended ways to "reengineer" engineering education [7]. This volume further suggested that education researchers investigate both the processes and products of engineering undergraduate programs—whether products (e.g., students with certain skills) meet desired specifications and whether processes (e.g., student experiences) align with program goals and effective education practices.

It is significant to be considering the focus of these two reports in the aftermath of the very year of 2020, in which their predictions came to bear in an almost surreal style. Ironically, the four alternative scenarios provided to magnify the imaginative power of *The Engineer of 2020* report—scientific revolution, biotech takeover, natural disaster, and global conflict and collaboration—find simultaneous actualization in the year of 2020.A global pandemic has taken the lives of millions and disrupted billions more. The profound distrust displayed by major powers for a shared global future casts great uncertainty to the prospect of free exchange of goods, services, and knowledge, as well as the international commitment to solving humanity's grand challenges through collaboration. It will take time for engineering educators to fully absorb the impact of the recent global development on their business: the pandemic forces the closure of numerous engineering labs and disrupts research activities; travel restrictions keep international students away from college campuses. At the same time, numerous engineers in universities, companies, and other organizations stepped up in the design and manufacturing of personal protective equipment, the storage and transportation of vaccines, and in other ways helped mitigate the damage of the pandemic. Teachers and students who cannot meet in the classroom get together online to sustain learning, and some engineering educators have found creative ways to engage students in important, experiential aspects of engineering learning, such as design and building, outside the lab. These dramatic changes are likely precursors of upcoming paradigm shift in how we educate younger generations of engineers.

To assist the global community of engineering educators in anticipating the hopefully soon to arrive post-COVID engineering education, this paper examines the current policy discourses of two of the world's most important nations for educating engineers: The United States and China. As we hope to show in the following analysis, engineering education policies in the US and China, while sharing consensus on some important aspects of engineering in the future, also demonstrate notable differences in their respective articulation of the core values of engineering and the major roles to be played by engineers. Furthermore, while policy communities in the US and China both convey optimism about their national engineering workforce, we argue that both policies seem under-ambitious in envisioning the social and public characters of engineers, measured against the vision laid out in *The Engineer of 2020* report. We elaborate this argument at the end of this paper and share our thoughts on exploring globally and nationally relevant visions of engineering education.

While comparative policy analysis is common in research of higher education [8], cross-national studies of engineering education policies are still limited in scope. Our approach in this paper is informed by prior works comparing conceptions of engineering competency in the US, Europe, and Latin America [9], comparisons of policy documents between leading engineering organizations [10], and historical work on national patterns of engineering education development [11]. These exemplar studies illustrate the importance of paying close attention to the dynamic between the international homogenization of engineering education and practice on the one hand, and the distinct priorities, patterns of professional employment, and cultural beliefs about engineering in the hosting nations on the other. These theoretical insights alert us to remain sensitive to the contexts in which policy documents are formulated, and to the ways in which policy texts embody efforts to synthesize domestic and international discourses of engineering development.

In this paper we focus on two recent reports:

- The US NAE 2018 report, *Understanding the Educational and Career Pathways of Engineers* ("the Pathways Report" hereafter) [12]
- The Chinese Ministry of Education 2017 policy documents that together outline the initiative, Emerging Engineering Education (3E) [13-15]

The NAE Pathways report resulted from a study commissioned by the Academy to "understand characteristics and career choices of engineering graduates, […] as well as the characteristics of those with non-engineering degrees who are employed as engineers in the United States" [12].

Authors of the report, consisting of faculty members inside and outside engineering disciplines, university administrators, and corporate leaders, sought to sustain the supply of competent engineers in the US by investigating "the engineering education-to-workforce pathway."

Around the same time that the NAE study was conducted, engineering educators and policy makers in China were engaged in a series of conversations aiming at renewing China's engineering education for the next thirty years. These conversations laid the groundwork for the Emerging Engineering Education (3E) initiative, announced officially by China's Ministry of Education in 2017 [13-15]. Since its announcement, the MoE has funded clusters of projects in engineering education research and practice that seek to define this emerging pattern. In addition, a series of academic articles, authored by influential policy thinkers, including university presidents and officials at the MoE, help elaborate the background, objectives, and implications of the 3E policy [16-19]. The official 3E policy documents are quite succinct in stating the goals and strategies of engineering education reforms. To provide more context about the policy discourse, we also examine four academic articles that aim to interpret the policy, authored by scholars who participated in the conversations that led to the formulation of the official 3E policy documents.

The following three sections present a close reading of the NAE's Pathways report in conjunction with the official policy and three influential academic articles about the 3E initiative in China, in attempt to answer three research questions: 1) What assessment of engineering education in the US and China motivated the NAE study and the 3E initiative? 2) What visions of engineers and engineering education are advanced in the respective policies? 3) Accordingly, what changes in engineering education are recommended for fulfilling the visions proposed in the policy documents? The main answers to the three research questions are summarized in Table 1. Next, we compare the similarities and differences between the US and Chinese policy discourses about engineering education in a discussion section, while situating the comparison in the two nations' respective social, political, and cultural characteristics. We conclude this paper by critically assessing both policies in the global context of engineering education. In particular, we discuss the implications of this policy analysis for maintaining engineering as an active force in creating a just and sustainable global future.

Motivating Considerations for the Pathways report and the 3E Policy

In contrast to previous assessments [20], authors of the Pathways report undertook their study with an optimistic evaluation of the overall status of engineering education in the United States. The charge of the NAE Committee on Understanding the Engineering Education-Workforce Continuum centers on sustaining and strengthening this positive trend, manifested particularly by a thriving economy powered by technological innovation, and engineering graduates' relative advantages in career flexibility, job satisfaction, and salaries. This positive picture, says the report, contrasts sharply with messages in "the popular and trade press" that are "rife with concern that the United States is losing its technology edge and that engineering education-to-workforce pathways may not be functioning as effectively as needed to sustain US technological and economic leadership." The report therefore serves in part to counteract hyperbolic rhetoric that paints a gloomy picture of US engineering, which has no foundation in empirical data.

Table 1 Motivations, Visions, and Recommendations in the Pathways Report and the 3E Policy

		Pathways Report	3E Policy
Motivating considerations		• Sustaining and strengthening the positive trend of US engineering education • Counteracting misleading media reports • Promoting an engineering education-workforce pathway perspective	• New demands from global technological breakthroughs • National development strategies • Quality enhancement for the engineering education system
Visions	**Engineers**	• Multidisciplinary knowledge and computing thinking • Professional skills • Considering sustainability, societal impact, and public policy	• Analytical thinking, design thinking, critical thinking, and digital thinking; innovative and entrepreneurial • Knowledge and professional skills for problem solving • Commitment to serving national and social needs
	Engineering Education	• Ensuring continuous US competency and leadership in global tech-based economy	• Meeting national needs through producing engineering talents • Transforming engineering disciplines • A driver for technological and economic innovation • From "adapting" to "shaping" the future
Recommended changes		• Addressing persistent diversity and inclusion challenges • Adopting evidence-based pedagogy • Partnership with diverse stakeholders	• Overhauling the landscape of engineering disciplines • Innovating industry-university-research collaboration • Cultivating engineers' innovative and entrepreneurial abilities • Exploring interdisciplinary engineering training

Instead of spreading false alarms, the report aims to sustain and strengthen the engineering labor force in the US, and it attempts this goal through promoting an engineering education-workforce pathways perspective. Authors of the report find that the majority of engineering graduates in the US do not remain working in narrowly defined engineering jobs, but the skills developed in engineering training continue to play essential roles in the success of these graduates, regardless of their career affiliations. As a result, the report suggests that a pathway perspective can better capture the diverse picture and fluid migration of engineering workforce in the US. In addition, the Pathways report identifies the underrepresentation of women and ethnic minorities in engineering as a major threat for the continued prosperity of US engineering.

For policy thinkers in China, the 3E policy is grounded in China's national development strategy, formulated in response to global technological and economic development. First, the policy documents recognize a new global wave of industrial revolution and new business practices enabled by technological breakthroughs in areas such as Internet of Things, Big data, Artificial

Intelligence, New Materials, and New Energy. These technical and business trends, according to the 3E policy, pose new demands for the engineering community [13]. Second, in response to global technical and economic changes, China has committed to national strategies of building an innovation-driven economy, for which engineering plays important roles in a series of strategic initiatives, such as "Made in China 2025", "Internet +", "Network Power", and the "Belt and Road" initiative [16]. Third, the assessment of global conditions and national strategic development highlights the need for reforming the nation's engineering education system.

Holistically, these policy documents recognize that China has the world's largest higher engineering education system in terms of the number of yearly graduates, but engineering education in China is not yet comparable in its quality and influence to global leaders like the US and Germany. E3 thus calls for new paradigms of engineering education in order to produce competent engineers and to meet the talent needs for an innovation driven economy. Notably, the technological breakthroughs used to set the context for this initiative parallel the scenarios that undergird the earlier NAE Engineering of 2020 project, though they are largely absent from the more recent NAE Pathways report. Similarly, the concern for the competitiveness of the national engineering workforce in comparison to major global players coupled with the calls for innovation in engineering education, also parallels the logic that drove *The Engineer of 2020* report and its intended outcomes.

Visions of Engineers and Engineering Education for the Future

According to the Pathways report, the required competency for future engineers is shaped by the developmental trends of engineering practice, the needs of employers, as well as engineers' active demand in assuming leadership in efforts to build a sustainable and socially just future. To begin with, the report notes emerging changes in engineering practice, propelled by "rapid advances in many fields of science and technology." These emerging changes, suggests the report, further highlights future engineers' ability to integrate knowledge from multiple disciplines, and to exercise computing thinking. At the same time, the report recognizes a "growing demand from industry for engineering graduates to be equipped with nontechnical or professional attributes and abilities in addition to their technical aptitude." Lastly, the report acknowledges that a number of engineers have recently begun to incorporate considerations such as sustainability, societal impact, and public policy in their work. Notably, the substance of the engineering competencies espoused in the Pathways report differ little from the statements in *The Engineer of 2020*, yet authors of the Pathways report explicitly distinguish the technical, professional, and social dimensions of the engineering competency and attribute them to three distinct groups of stakeholders.

Based on assessment of the core competency for future engineers, the Pathways Report identifies the main goal of engineering education as "ensur[ing] that US-based engineers have the technical and professional skills required to compete globally and meet the needs of the nation in the future," which requires the US engineering education system to "continuously adapt both to advances in science and technology field," and "to the changing needs of industry, society, and workers themselves." Yet as noted earlier, the tone is rooted more in a sense of ongoing technological progress and leadership rather than sense of impending threats and crises evoked by the scenarios used in developing *The Engineer of 2020*.

According to the policy texts that elaborate the 3E initiative, three major dimensions characterize the demand for future engineering competency. First, while the core of engineering continues to require analytical thinking and design, recent developments in engineering also call attention to the importance of critical thinking and digital thinking. In addition, leaders in engineering education increasingly stress a variety of capabilities in innovation, entrepreneurship, and the ability to integrate thoughts and knowledge in multiple disciplines. Second, from the employers' perspective, the 3E policy highlight engineers' competency in discipline-based as well as in interdisciplinary knowledge, technical and professional skills, all of which are essential in solve practical engineering problems [14]. Third, the 3E policy states the necessity for engineers to have a strong sense of "responsibility for the nation," demonstrated in their commitments to the progress and improvement of society via defining, analyzing, and solving pressing societal problems. To build a cadre of world class engineers, the 3E policy also spells out the necessity for engineers to develop a passion for lifelong learning, a global vision, as well as awareness to ethical, legal, and ecological issues.

The 3E policy also places additional demands on the community of engineering education as an institutionalized sociotechnical force central to advancing the nation's industrial and economic agendas. First, like its counterpart in the US, engineering education in China is expected to help the nation stay ahead in global economic competition by producing industrious and innovative engineers [18]. To meet the future need for engineering talent, the 3E policy calls on engineering educators to actively partner with the industry in anticipating the direction of technical and economic development, using the projection as a basis for adjusting the directions and contents of educational programs [13]. Second, the 3E policy expects to transform the units of engineering education—departments, colleges, and institutions—into hotbeds for groundbreaking technological research and development via reorganizing research and educational resources to nurture cross-fertilization of knowledge and expertise from science, engineering, and humanities disciplines [14]. Ultimately, the 3E policy envisions engineering education to be a powerhouse for an innovation driven national economy. Finally, authors of the 3E policy documents look upon the engineering education community as pioneers in actively anticipating and shaping the future of global and national socioeconomic and technical development, and in so doing, transcending an "adaptive" mentality that has for a long time positioned engineers as "followers" of social and economic changes. Much of this description of the expected role of engineering education in national development showcases the influence of *Educating the Engineer of 2020*, an indicator that policy thinkers in China are aware of impactful conversations about engineering education in other nations.

Recommended Changes to Engineering Education

As a key point, the Pathways report points out that the US engineering faces a persistent diversity challenge, where "white and Asian males constitute the vast majority of employed degreed engineers and those who work in engineering occupations." Accordingly, much of the report's recommendations for changing US engineering focus on enhancing diversity and inclusion. The recommendations range from addressing chilly climate concerns in engineering schools, to anti-bias training in companies, to better communicating the value of engineering degrees to K-12 students. The report also calls upon engineering education researchers to collect more data so as to provide a more comprehensive demographic picture of US engineers and engineering students.

Besides attention on “who” become engineers, the Pathways report also encourages educators to improve the “how” of engineering learning by adopting evidence-based pedagogy in order to enhance student engagement. The report recommends educational innovation developed or verified by engineering education research, including “active and experiential learning and other student-centered practices that promote real-world applications of STEM concepts to complex sociotechnical problems like those that engineers will face in their work.” In response to the growing importance of computing in engineering practice, the report specifically calls for engineering educators and administrators to “pay more attention to Computer Science (CS)” and “continue to incorporate computing/CS more pervasively into engineering degree programs.”

Finally, advancing a multi-sided, pathways perspective, the Pathways report encourages engineering educators to form partnership with alumni, employers and engineering professional societies in order to bring real-world engineering experiences into engineering programs and to prepare engineering graduates for a variety of employment opportunities.

On their part, policy thinkers for Chinese engineering education seek to meet the needs of industry and to build a new landscape of engineering disciplines. Inspired by these goals, they recommend re-examining the educational objectives and the scale of training at all levels of engineering education (professional, undergraduate, master, and doctoral levels) according to the required competency of future engineers [19]. The 3E policy also stresses accelerating the development of emerging engineering majors while transforming and upgrading traditional engineering majors, in order to make engineering education a more agile force in supporting the development of industry. The policy aspires to renew the landscape of engineering disciplines in China by combining emerging and traditional engineering majors [18].

In addition, the 3E policy recommends stakeholders of engineering education explore an innovative model of the industry-university-research collaboration. The policy recognizes that engineering education is a complex and systematic project involving multiple industries, departments, and institutions, thus concerted efforts from the government, industry, and universities are critical in ensuring successful transformation of the national system of engineering education [19]. The policy accordingly stresses reliance upon the Multi-Partied Cooperative Education (*Duo Fang Xie Tong Yu Ren*)—a concept that acknowledges the shared responsibility of education by universities, industry, and the government—as a way of overcoming systemic and institutional barriers for broad participation in talent training, and promoting the integration of science and education, industry-university integration, school-enterprise cooperation [15].

Resonating the national ambition in building an innovation-driven economy, the 3E policy also calls attention to strengthening the cultivation of engineers’ innovative and entrepreneurial abilities. The policy envisions a "creative-innovation-entrepreneurship" education system for engineers, which aims to increase the employment of college graduates via innovation and entrepreneurship, particularly through supporting incubators for student entrepreneurs, maker space, and other platforms for innovation and entrepreneurship [15]. The policy stresses the importance of integrating innovation and entrepreneurship education into professional training with real-world, cross-border issues, ill-structured problems, and future-oriented projects; it also advises the cultivation of crisis awareness, innovative spirit, innovative thinking, and entrepreneurship capabilities throughout the entire processes of engineering learning [19].

Finally, authors of the 3E policy encourage the exploration of interdisciplinary models of engineering training. The policy recommends the formation of new, interdisciplinary types of organizations by comprehensively considering interdisciplinary, multidisciplinary, school-enterprise, industry-university-research, teaching-research and other integration innovation and talent training models [16]. At the curriculum level, the policy encourages creation of interdisciplinary courses and curricula that feature complex engineering problems, interdisciplinary teaching teams, interdisciplinary project platforms, and cooperative learning experiences [17].

Discussion

A comparison of the main similarities and differences between the Pathways Report and the 3E Policy is presented in Table 2. The two policies endorsed by NAE and MoE demonstrate similarities in three main areas: First, both policies are grounded on similar assessment of the global macro-environment for engineering education. Second, the authors of both policies follow a similar systems perspective to engineering education, which takes into account stakeholders inside and beyond institutions of higher education and considers a broader education-workforce pathway. In accordance with this systems or “ecological” perspective, the policy texts in both nations demonstrate their third major similarity in deriving statements of engineering competency that are based on anticipations of multiple stakeholders’ needs.

Table 2 Main similarities and differences between the Pathways Report and the 3E Policy

<table>
<tr><th colspan="2"></th><th>Pathways Report</th><th>3E Policy</th></tr>
<tr><td colspan="2">Similarities</td><td colspan="2">• Assessment of trends in global engineering education
• Advocacy/Endorsement of systems perspective of engineering education
• Key competencies for future engineers are shared by engineering practices, employer demands, and engineers’ leadership aspirations.</td></tr>
<tr><td rowspan="3">Differences</td><td>Authorship</td><td>• Advisory body</td><td>• Government body</td></tr>
<tr><td>Policy Culture</td><td>• Multiple voices, professional expertise prioritized
• Bottom-up logic of presentation</td><td>• Education administrators and regulators prioritized
• Top-down logic of presentation</td></tr>
<tr><td>Conception of Engineering</td><td>• A set of technical and professional skills
• An asset</td><td>• A means to meet social and economic needs
• Focus on disciplines</td></tr>
</table>

The American and Chinese policy authors exhibit significant convergence on their respective assessment of the macro-environment and of the major global forces that will shape engineering education in the foreseeable future. In particular, both policies underscore the key influences of scientific and technological breakthroughs, the new economy (characterized by the tide of the

Industrial Revolution 4.0), as well as emerging industries catalyzed by knowledge innovations on the horizon.

Conceptually, both policies are based on, and attempt to advance, a broader, systems perspective of engineering education, the purview of which stems beyond institutions of higher education. This broadening of perspective is embodied in the NAE report's explicit promotion of the "education-workforce" pathway. Based on the assumption that higher education only accounts for a part of the full picture of national engineering workforce, the Pathway report defines a wide range of stakeholders, including faculty members and administrators in engineering schools, but also extending the range to encompass K-12 teachers, high school counselors, parents, and students on the pre-college end, as well as industry, employers, and alumni on the post-college end. The 3E initiative, on its part, stresses "multi-partied cooperative education" (*Duo Fang Xie Tong Yu Ren*), which formally recognizes the role of educational institutions, industry, and government in steering the educational ecosystem in ways to fulfill the needs of engineering talent posed by social and economic sectors.

Finally, based on a similar assessment of the macro-environment and systems views of engineering education, the Pathway report and the 3E policy make similar statements about the key competencies required from future engineers. In both policies, these competencies are shaped by three sources: 1) developmental trends in engineering, such as the blurring of traditional disciplinary boundaries, which require interdisciplinary knowledge and integrative ways of thinking; 2) the employers, who value engineers' professional skills like communication and teamwork; and 3) requirements for engineers to lead social changes, which emphasize contextual knowledge, listening skills, and ethical values, such as concerns for social justice and sustainability.

The American and Chinese engineering education policies demonstrate major differences in two aspects: the culture that shapes the formulation of education polices; and the conception of engineering.

The differences between the US and Chinese policy cultures are signaled in the authorship and narrative styles of the Pathway report and the 3E documents. As we note in the Introduction, authors of the Pathway report consist of university administrators, faculty members, and (retired) corporate managers/executives. The composition of the authors exhibits an attempt to balance multiple, though not fully comprehensive, voices in the policy discourse about engineering education. Notably, the positionalities of the authors seem to emphasize their professional expertise—instead of solely administrative positions—as the source of legitimacy in policy making. Moreover, the National Academy of Engineering, though established by the U.S. Congress and charged to report to government agencies as requested about pressing issues of science and technology, is a "private, independent, non-profit institution" [21]. Its reports, however, are in the form of analyses and recommendations rather than mandates, and the NAE itself has no authority to fund its recommendations.

In contrast, the 3E initiative is an official program from the Ministry of Education in China, and the major academic articles that provide the most authoritative interpretations of the policy are authored by MoE officials and incumbent/former university presidents. The 3E initiative thus reflects more explicitly the perspective of engineering education administrators and regulators, with the legitimacy of the policy drawn in important ways from regulatory and administrative power. That said, we should note that the authors of the 3E texts, while taking administrative roles, are also scholars of engineering education. Furthermore, official, administrative documents of engineering education reform in China are also supported by policy research that include inputs from multiple stakeholders.

These differences between the American and Chinese policy cultures are partly embodied in the narrative styles that characterize the respective policy documents. The Pathway report follows a "bottom up" logic to the extent that its findings and recommendations are grounded on rich empirical data about engineering enrollment and workforce. In comparison, the 3E policy seems to follow a "top down" logic of presentation, beginning with an overall assessment of global trends, and then proceeding to national level, and finally, education specific analysis.

The MoE and NAE policies also highlight key differences between Chinese and American policy thinkers' conceptions of engineering. Authors of the 3E policy conceive engineering as highly organized collective activities to serve important social and economic needs. Hence, the 3E policy places demands of future economic, industrial, and social development at the center for determining the objectives of future engineering education, which in turn shape the desirable competencies for future engineers. Moreover, the literal expression of the 3E in the Chinese language—New Engineering Disciplines (*Xin Gong Ke*)—highlights academic disciplines as the chief locale for innovating engineering education. In this sense, the 3E policy represents the national will to renew outdated engineering disciplines while making space for emerging disciplines in the educational arena. This keen attention to the disciplines might be understood in the context of China's higher education governance, where "First Level Discipline" and "Second Level Discipline" are approved by the State Council and hence assume a quasi-legal status [22].

While also recognizing the role of engineering in advancing social and economic agenda, the Pathway report embraces a more fluid view of engineering, considering it primarily as a set of technical and professional skills. This fluid view is in important ways informed by the report's finding that a significant proportion of engineering graduates in the US do not work as narrowly defined "engineers," yet they rely heavily on the analytical abilities and professional skills—developed primarily in their engineering training—to achieve success in a broad variety of careers. According to this perspective, engineering training is an asset for those who manage to receive it. This individual-based, asset view of engineering education is manifested in another key concern spelled out in the Pathway report: the diversity and inclusion in engineering education. Besides stressing the value of diversity in enhancing the competitiveness of US engineering, the asset view underscores the justice dimension of a diverse and inclusive engineering education-workforce pathway: given that engineering education serves as a precursor to prosperous careers, wider and more equitable allocation of this asset becomes a necessity of social justice.

The findings here, then, extend and contribute to previous discussions of the ways in which conceptions of engineering are closely linked to national agendas and imperatives. Like earlier works by Downey, Lucena, and others [9-11, 23], this work highlights the ways in which engineering, though often conceptualized as a global profession, is inherently tied to national interests. These national interests, moreover, exert pressure – overtly through government programs or implicitly through national reports – on the engineering education system.

Conclusion

This paper reviews and compares the NAE Pathways report and China's 3E initiative. In particular, we examine 1) the factors that motivate the NAE study of the engineering education-workforce continuum and China's new policy initiative for engineering education reforms, 2) visions of future engineers and engineering education laid out in the two policies, and 3) specific changes recommended to US and Chinese engineering education aiming at the actualization of their respective visions.

We find that the two policies are based on similar assessment of global trends of technological and economic development. In addition, both policy communities adopt a systems approach that considers not only higher education institutions but also a broad range of stakeholders of engineering education. The similar assessment and approaches in turn drive policy scholars in both nations to make similar predictions about the core competency for future engineers. Meanwhile, we argue that the policy texts reflect different policy cultures in the US and China, and both policy communities' pursuits of innovating engineering education are informed by different conceptions of engineering [23]. Clarifying the respective priorities and concerns of US and Chinese policy influencers and advisors and the cultural contexts in which their priorities and concerns take shape, we hope, would assist engineering educators to appreciate the differences between the two nations' systems of engineering education.

Readers concerned about the liberal education of engineers might find the two policies informative for thinking about the integration of STEM disciplines with the humanities, social sciences, and arts. Both policies take note of the further blurring of disciplinary boundaries and recognize the need for engineers to be equipped with knowledge and skills in engineering as well as in natural and social sciences, humanities and arts. In particular, China's 3E initiative, while attempting to retain the academic discipline as the unit for organizing engineering education, seeks to reimagine the meaning and the boundaries of discipline [19]. This mixed philosophy indicates policy thinkers' attempt to address the tension between the practical and the administrative aspects of engineering education in China: whereas the reality of engineering practice knows no disciplinary boundaries, academic resources (faculty, institutional structures, etc.) are still largely organized along disciplinary lines, as a result of the nation's higher education governance structure.

Furthermore, we attempt a critical appraisal of the two policies as we aspire to envision engineers' role in building a just and sustainable global future. The current global pandemic heightens the urgency of facing—not evading—engineers' global and social responsibility. Perhaps few moments are as equally pressing as the present one for us to ask questions like whether engineering contributes to or combats health inequity, what engineers are doing to resist anti-scientific ideas that threaten public health, or what engineers can do to increase the supply of medical devices, personal protective equipment, and enhancing the availability of vaccine worldwide.

In comparison to previous, more alarming assessment of engineering education in the US [17], the Pathways report conveys a clear sense of optimism. Using rich datasets, the report delivers a reassuring message about the competency of US engineering workforce, while affirming engineering education as a viable and profitable pathway toward prosperous individual careers. While this affirmation works partly to correct hyperbolic rhetoric that spreads unwarranted worry about US engineering, the arguable complacency implied in the report is nevertheless worth unpacking. While engineering schools seem to set their graduates on the right path of individual prosperity from an economic standpoint, questions of engineers' role as champions for social well-being and guardians of public safety and health, should perhaps play a more central role in the evaluation of engineering education as a collective enterprise.

Such questions become all the more urgent amid an ongoing global pandemic, as we suggest in the Introduction. In a way *The Engineer of 2020* report already warns us of the vulnerabilities lurking in a globalized technological civilization: an aging population, fragile infrastructure, and threats of natural disasters. The COVID-19 pandemic is a powerful testament to the destructive power of biohazard and natural disasters, which is then magnified by outdated healthcare infrastructure—in both developed and developing countries—and the vulnerability of elderly people. The problematic reality at present demands us to ask: to what extent have engineering educators systematically integrated the thoughtful visions and cautions laid out in *The Engineer of 2020* in the past two decades? In particular, how much have we dedicated ourselves to educating engineers who are not only competent functionaries in the global economy, but also committed citizens who take lead in advancing social cohesion and resilience? For example, referring to the discussion of promoting public understanding of science and technology in *The Engineer of 2020*, how often today do engineers explain the importance of facial masking, social distancing, vaccination, and otherwise encouraging adherence to public health requirements? To take a step further in this investigation of engineers' role in social change, we cannot help but questioning the efficacy of the Pathway report's recommendation of an information campaign, accenting the profitability of engineering careers, as the major measure to attract more women and underrepresented minorities to engineering, when high school students and their parents encounter news or living experiences of gender and racial injustice on a daily basis.

Finally, we note that the Pathways report's analysis of globalization focuses on heightened economic competition, resulted from global movement of goods, information, and technical talent. Following this analytical approach, the report keenly calls on policy scholars to assess the impact of foreign-born engineering students who study in the US with temporary visas. Yet the size of this particular cadre of engineers is likely to shrink as new restrictions are imposed on international students due to the pandemic as well as adjustment in the receiving nations' immigration policies. Overall, the Pathways report endorses one particular perspective—the competitiveness of individual US engineers—in its assessment of globalization, while saying little about global competition, exchange, and cooperation in politics, health, climate, culture, and other important areas.

While sharing the NAE's view on globalization as a catalyst for economic and technological competitions in the global market, China's 3E policy also rests partly on concerns over global competition in the quality and influence of national engineering education systems. The 3E documents note that China has become the number one producer of engineering graduates in the world, a testimony of the scale of the nation's engineering education. This growth in the size of engineering education drives policy thinkers in China to pay more attention to the quality of its educational system and its influence on the global stage. The 3E policy, conceived partly as vision statement for new paradigms of educating engineers, represents the authors' ambition to articulate and facilitate a "Chinese model of engineering education" [15]. In this sense, the 3E initiative reaffirms China's willingness to remain an active player in the global community. Yet the vision for China's future engineers laid out in the 3E policy seems too narrowly conceived, and inadequately engaging with pressing global challenges, to match the ambition of global leadership expressed in the policy documents. It is one thing to acknowledge that engineers in any domestic context will be participants in global economic and technological competitions, contextualized by technological trends, such as 5G and industry 4.0. It is quite another, however, to envision the engineers to assume leadership in a shared sociotechnical future for humanity. To this latter objective, the 3E policy has little to say.

Herein lies perhaps a key question for educators who support a truly integrated education for engineers in the future. No doubt, competent engineers in the future need interdisciplinary perspectives for harnessing the opportunities brought about by technological innovation, but perhaps they need also to approach engineering as a "way of being" [24], one that prepares them to ask different sets of questions—different from how they are going to survive global competition of technical labors—as the first step to reveal and to actualize the values that make engineering a truly aspiring choice for young members of the global community.

Acknowledgements
Authors Xiaofeng Tang, Zheping Xie, and Haiyan Zhao acknowledge the support of the Engineering Education 111 Project (B20073).

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