Toward a Cross-cultural Conversation: Liberal Arts Education for Engineers in China and the U.S.

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Introduction

A decade ago, University of Vermont's Dean of Engineering and Mathematical Sciences Domenico Grasso raised an existential question to American engineering educators. Noticing that Asian countries were producing engineers at a much higher rate than the U.S., and engineering graduates from Asian universities are "every bit as technically competent as their American counterparts," Grasso questioned whether it is wiser to close all the expensive engineering colleges in the U.S. and "simply import all the engineering we need."[1] As a lifetime engineering professor and administrator, Grasso was certainly not proposing laying off thousands of American engineering educators. Instead, he urged his colleagues in the U.S. to pursue "a fresh start" and to educate "[a] growing and increasingly diverse number of domestically trained engineers—equipped with the broad insight and critical thinking skills the world needs" through "[the] study of the human condition, the human experience, [and] the human record." Doing so, Grasso suggests, would give the engineers educated in the U.S. "a competitive advantage over their foreign counterparts."[2] Grasso's own educational practice exemplifies the kind of broad education he advocates for: He founded the Picker Engineering Program at Smith College, the first ABET accredited engineering program in a women's liberal arts college, a program that "help[s] students hone their critical thinking using techniques usually associated with study in the liberal arts and through structured problem solving, which is typically associated with an engineering education."[3]

Like Grasso, a number of American engineering educators consider the broad education in the humanities, social sciences, and the arts an important strength of engineers educated in the U.S.[4] Yet the U.S. is not—at least no longer—unique in reserving a space for what is traditionally called the liberal arts in engineering programs. Whether under the name "liberal arts education," "liberal learning," or "general education," educators across the globe have engaged engineering students in the study of philosophy, history, politics, sociology, and economics. In January 2015, an NSF sponsored workshop on "Liberal Studies in Engineering" gathered some fifty participants from the U.S., Europe, and Asia, who spent two days energetically discussing and debating the purposes, strategies, and challenges of educating engineers in the liberal arts. Attendants from outside the U.S. also introduced the distinct practices of liberal education for engineers in different institutional and cultural contexts. The discussion and debate continued in two special issues of *Engineering Studies*.[5] The spreading of liberal arts in global engineering education is in part assisted by international accreditation agreements, such as the Washington Accord, which drive many countries to adopt an outcome based accreditation system and to require similar technically and socially related competencies from engineering graduates.[6] Besides regulative factors, the globalization of the engineering workforce has generated profound needs for engineers with broad knowledge and skills. In response to these needs, some universities and colleges have combined engineering learning with study of foreign languages in international engineering programs. However, practicing engineering in different legal, business, and cultural contexts requires professional and personal competencies that go beyond language abilities: a truly global engineer needs to demonstrate appropriate understanding of local history, politics, and culture; to respect different ways of thinking and acting; and to communicate with stakeholders coming from diverse background. In a word, a successful global engineer is not only a competent technical expert but also a resourceful, caring, and well-rounded person. These attributes are the objectives of a liberal arts education.[7]

In this paper, we argue that it is critical to create and sustain conversations across nations and cultures on educating global engineers, professionals who are well versed in technoscience and in the liberal arts. We provide three reasons for this argument. First, in order to prepare students for global engineering practice, educators need a robust understanding of how engineers are educated in other parts of the world. Second, as the Liberal Studies in Engineering Workshop and the resulting articles in *Engineering Studies* indicate, educators have not come to agreement on a well-established paradigm for educating engineering students in the liberal arts. For example, engineering educators from Europe tend to differ a lot from their American colleagues on questions like what a liberal arts education stands for and how it contributes to the preparation of engineers. Given such difference of opinions, cross-cultural discussions and debates will continue to generate insights regarding the visions and strategies of this important educational reform. Third, in spite of the diverse visions of and approaches to educating engineers in the liberal arts, attempts of this kind confront some common challenges throughout the world, such as the marginal position of the liberal arts in the engineering curricula. A cross-cultural conversation would enable liberal educators for engineers to share strategies and eventually overcome the widespread challenges.

While a full-blown cross-cultural conversation would include educators and students from the economically developed and developing regions as well as Western and non-Western cultures, we pursue a more modest goal in this paper: a brief comparison of the objectives, strategies, and challenges of educating engineers in the liberal arts between China and the U.S. While the scope of comparison is limited, we seek to demonstrate that liberal education for engineers in both countries encounter some similar challenges. We argue that a conversation between the two cultures will generate intellectual resources for productively meeting some of these critical challenges.

The body of this paper is organized in three sections. Section one introduces educational reforms in China and the U.S. that seek to expand engineers' learning in the liberal arts. Drawing on the literatures of higher education in engineering in Chinese and English, we compare the respective objectives of liberal arts education in engineering pursued by Chinese and American educators. Section two examines some institutional, curricular, and instructional strategies for educating well-rounded engineers in both countries. In this section, we briefly introduce the programs of general education in two Chinese engineering universities and compare them with three American engineering programs. Section three reflects upon the challenges faced by educators in China and the U.S. in their attempt to bring together engineering and the liberal arts. These challenges, in our analysis, reflect a more common instrumental attitude that works against the expansion of professionals' non-technical learning. To counteract this narrow and instrumental view, we suggest a broader approach, one that fully appreciates the critical and emancipatory spirits in the liberal arts. While the challenges for broadening engineering learning in China and the U.S. are associated with distinct governance structures and professional cultures, pioneering educators in each country have drawn from different intellectual resources and developed local strategies to meet these challenges. Therefore, we conclude by proposing a global community of liberal educators for engineers, one that facilitates sharing of intellectual traditions, educational visions, and strategies. Such a community, we argue, would inspire more productive answers to our common challenges.

Section One: General Education in China and Liberal Arts Education in the U.S.

When speaking about educating engineers in the non-technical areas, terms like "liberal education," "liberal arts," and "general education" often cause confusions. In many cases these terms are interchangeable, but elsewhere they indicate profoundly different philosophies of education.[8] According to Hu and Cao, liberal education represents an educational ideal, "a learning methodology that enables individual learners to deal with complexity, diversity, and change," whereas general education is one approach to implement the idea of a liberal education by exposing students "to diverse disciplines, laying the foundation for developing important intellectual, practical, and civic capacities."[9] This interpretation of general education is very similar to the idea of a liberal arts education in the U.S., which refers to learning outside the domain of professional training. In contemporary usage, "liberal arts" usually refers to subjects in the humanities, social sciences, and the arts.[10] As the concept of "general education" has gained significant attraction in Chinese higher education as a result of a national, government-directed movement, we use "general education" to describe programs in China that facilitate engineering students' learning outside their majors. We refer to similar efforts in the U.S. as "liberal arts education."

Higher education in China during the early days of the People's Republic had been heavily influenced by the Soviet Union, especially by its emphasis on specialization. In the 1950s the state government ordered a nationwide Adjustment of Colleges and Departments. Under the state mandate, dozens of independent engineering colleges were set up. Meanwhile, many departments of humanities and social sciences were cancelled, removed from the hosting universities, or merged with similar departments in other institutions. A major consequence of the Adjustment was the dominance of narrow, specialized education in China's universities and colleges. This state of affairs started to change by the late 1970s as the government embraced the Reform and Opening Up policies. As China sought to compete in the global economy, the limitations of a narrowly focused and highly specialized education became increasingly obvious. In 1995, the Ministry of Education hosted a national conference on "Cultural Quality Education," which marked the beginning of a national movement to promote college students' "cultural qualities." Since then, more than a hundred "Cultural Quality Education Bases" have been established in universities. Although the government grants the cultural quality education an important and strategic role in modernizing China's higher education system, the connotation of such an education is not elaborated. In official documents, "cultural quality" is simply explained as "humanistic quality".[11] Scholars also argue that although the connotation of "cultural quality education" is narrower than a "general education," both are influenced by the same philosophy of education. Therefore, "cultural quality education" can be understood as the "general education" in China.[12] In the context of engineering education, Li and Shi suggest, this national movement seeks to "provide engineering professionals with the necessary skills to practice engineering, skills such as critical thinking, effective communication, collaboration with others, appreciation of diversity and integration of knowledge from science and the humanities in order to solve problems."[13]

Educating engineers in the liberal arts has a longer history in the U.S. than the "general education" movement in China. Bucciarelli reminds that Rensselaer Polytechnic Institute—the first civil engineering school in the U.S.—offered courses in languages and philosophy as early as 1850.[14] Over the past one and a half centuries, liberal arts education is considered to serve the engineering profession and engineering students in a variety of ways. Noble argues that the American engineering profession in the 20th century served primarily economic ends, especially those pursued by big corporations. As a result, decisions on what engineers should learn—both the technical and the non-technical—reflected widely shared expectations for engineers' contribution to economic growth.[15] From the Grinter Report in the 1950s to *Educating the Engineer of 2020* (published in 2005), learning in the liberal arts, especially in social and economic sciences, is recommended to enhance engineers' managerial skills, communication, teamwork, and other capacities that make them more competent in the economic sector.[16] While economic considerations have a strong impact on the professional training of engineers, the engineering profession—like many other professions—insists that what distinguishes a profession is its prioritizing of social good to profits. This interpretation of professionalism indicates that social responsibility is both a goal and a trademark for professional practice (compared with unprofessional ones, such as a trade). An important mission of engineering educators, therefore, is to implant in young engineers a deep sense of responsibility to the clients and the public.[17] This mission is largely delegated to teachers of history, philosophy, and other subjects in the traditional liberal arts. Besides contributing to the economic and ethical agenda of the engineering profession, learning in the liberal arts is also valued for the refinement of young engineers' "characters." For example, at the founding meeting of the Society for the Promotion of Engineering Education (the predecessor of ASEE), "a broad, liberal education in philosophy and arts" was recommended to engineers in order to develop their "power of observation," "sound judgment," "healthy mental assimilation," and "a cultivation of human qualities."[18]

This brief historical review indicates some similarities and differences in the ways engineering education is organized and governed in China and the U.S. For example, education reformers in both countries pursue similar objectives with the broadening of engineering education: the enhancement of engineers' professional skills and global competency. In addition, the movements to include the liberal arts in engineering education are significantly impacted by the economic needs in both countries. Compared with China, where the movements away from and back toward general education were initiated by governmental policies, professional organizations in the U.S., such as ASEE and the National Academy of Engineering (NAE), played a more salient role in promoting liberal arts in engineering education. Beneath the different mobilizing agencies, however, institutions of higher education in both countries are granted a lot of latitude to experiment with liberal arts education in engineering programs. As a result, educators apply a variety of "local" strategies to enrich the education of young engineers. We will examine some institutional, curricular, and instructional strategies in the following section.

Section Two: Institutional, Curricular, and Instructional Strategies

Higher education in China is primarily governed through the Ministry of Education. Although China has established an accrediting body for engineering education, the Ministry of Education still has significant impact over university curricula.[19] As Li and Shi note, undergraduate curricula in Chinese universities usually consist of three parts: 1) the Ministry of Education compulsory courses, 2) the cultural quality education courses, and 3) courses required by the major.[20] The Ministry of Education compulsory courses include political theories, foreign languages, military training, and physical education. Although the tenor of the compulsory courses is socialist political and economic ideas, the cluster of courses also contributes to students' general education by helping them develop the appropriate cultural, moral, and physical foundations to participate in social and civic life. The cultural quality education more visibly embodies each institution's specific approach to general education. In this section we present examples of general education in two engineering universities in China: Tsinghua University and Beijing Institute of Technology (BIT).

Tsinghua University was founded in 1911 as a preparatory school for Chinese students to study in the U.S. Therefore, the original curriculum of Tsinghua was designed following the American model of liberal arts education. This educational philosophy was changed after the founding of the People's Republic, especially during the Adjustment of Colleges and Departments in 1952, when most departments in the sciences, humanities, and social sciences were removed from Tsinghua and replaced by a number of engineering departments. The Adjustment made Tsinghua the flagship university of engineering and technology in China. Since the 1980s, Tsinghua has reinstated and created a number of schools and departments in the sciences, humanities, social sciences, and arts in an attempt to establish a comprehensive university.

During the 21st Tsinghua University Conference on Education in 2000 and 2001, Tsinghua redefined its undergraduate education as a "broad ranging professional education grounded on general education," a definition that recognizes the foundational role of general knowledge, learning skills, and cultural quality in the preparation of young professionals. The university's strategic emphasis on general education led to a "core curriculum of cultural quality education" in 2006. The core curriculum offers over 100 courses, grouped into eight categories: "philosophy and ethics; history and culture; language and literature; art and aesthetics; environment, technology and society; contemporary China and the world; personal life and development; and mathematics and natural sciences."[21] Every undergraduate student at Tsinghua is required a minimum of 13 credits in cultural quality education, with at least 8 credits or 5 courses from the core curriculum (courses in the core curriculum are worth 1 to 3 credits).[22] As engineering majors at Tsinghua usually require a minimum of 170 credits to graduate, the requirement for cultural quality education amounts to less than 10% of engineering students' total course credits.

Beijing Institute of Technology originated from the Yan'an Academy of Natural Sciences, the first science and engineering university created by the Chinese Communist Party. In 1951, the Academy was renamed Beijing Institute of Technology to represent its mission to develop the defense industry for the newly founded People's Republic. In 1988, BIT changed its identity from an exclusively engineering college to a comprehensive university that includes sciences, engineering, management, and the humanities.[23]

Undergraduate students at BIT need to take a minimum of 180 credits to graduate. Every undergraduate student at BIT is required to take at least 8 credits or 4 courses in the form of the general education electives.[24] Compared with other Chinese universities that specialize in applied science and engineering, the general education program at BIT is known for covering a broad range of topics in history and society, economics and law, literature and arts, linguistics, natural sciences, engineering and technology, as well as courses focusing on improving students' hands-on learning experiences.[25]

Pang suggests that the implementation of general education at BIT exemplifies a creative combination of Western educational ideas and Chinese cultural characteristics.[26] For instance, the development of learning outcomes for general education at BIT has been inspired by theories of educational psychology and learning sciences in the West. These learning outcomes are divided into three categories: knowledge, ability, and attitude. Some abilities that are central to general education at BIT are also listed in ABET EC2000, such as communication and teamwork. Meanwhile, Chinese cultural characteristics find their way into nearly every one of the learning outcomes. For instance, besides requiring knowledge of contemporary issues, BIT's general education also seeks to help students obtain a systematic understanding of the history and culture of the Chinese people, including significant historical events, figures, and thoughts as well as methods of evaluating historical sources in the context of China's political and ideological realities.

In addition to general education electives, BIT has designed a variety of extracurricular activities that aim to broaden students' intellectual, professional, and political perspectives.[27] These extracurricular activities, known as the "hidden curriculum" of general education at BIT, include the Communist Party branch and group activities, community service, and technological entrepreneurship events. Although participation in the extracurricular activities is not mandatory, over 90% of students take part in one or more of these activities.

As we note in the previous section, one thing that distinguishes engineering education in the U.S. from its counterpart in China is that the former is subject primarily to professional governance. In particular, ABET, the accrediting body for engineering education in the U.S., has the lion's share in affecting engineering curricula and pedagogies. Nominally, ABET's current outcome based criteria pay almost equal attention to engineering graduates' technically and socially related competencies.[28] However, critics argue that the education related to engineering students' non-technical competencies are often treated in superficial, tacked-on manners.[29] To change this state of affairs, some educators have sought to create holistic learning experience by integrating engineering and liberal arts education. In this section, we introduce three educational initiatives in the U.S. that seek integration of this sort. Two of them reside in liberal arts colleges: Harvey Mudd College and Smith College. The third represents a recent innovation in one of the nation's oldest engineering schools: Rensselaer Polytechnic Institute.

Though relatively unknown to the international engineering education community, Harvey Mudd College is a pioneer in innovating engineering education. Opened in 1957, it is a liberal arts college dedicated to the education of scientists, engineers, and mathematicians. The institutional design of this four-year residential college, with a student population of around 800, reflects its special mission to provide a liberal education to young scientists and technologists. The college has six degree-granting departments: Biology, Chemistry, Computer Science, Engineering, Mathematics, and Physics. In addition, a Department of Humanities, Social Sciences, and Arts attests to Harvey Mudd's identity as "a liberal arts college rather than just a technical school."[30]

Harvey Mudd's original curriculum design, resulted from a curriculum study in 1958, showcased its commitment to a broad, liberal arts education: students spend one third of their class time studying a Common Core curriculum, one third in their majors, and one third in the humanities, social sciences, and arts. Regardless of their majors, Harvey Mudd students take a Common Core curriculum for the first three semesters. The Common Core includes "sampler courses" from all the departments on campus; it is meant to provide every student with a broad and shared knowledge basis. An extensive curriculum in the humanities, social sciences, and arts is required to help students meet the objective engraved in the college's mission: "a clear understanding of the impact of their work on society."[31]

Harvey Mudd grants a general engineering degree. Teaching in the Engineering Department focuses on enhancing students' ability to learn by themselves and to solve unfamiliar problems. This philosophy is demonstrated in the entire engineering curriculum, but most visibly through a "design track" that includes three courses: Introduction to Engineering Design, Experimental Engineering, and the Engineering Clinic. In these courses, students confront open-ended and ill-structured problems that have no ready answers from textbooks or lectures. Students learn through collaborating in teams, trial and error, and acquiring new knowledge through the Internet or consulting more experienced professionals. The design track focuses not on knowledge transfer but on the development of learning skills. The ultimate goal is to prepare students for problems that will emerge in their future engineering practice.

Smith College is a well-known women's liberal arts college. In 1999, Smith College established the Picker Engineering Program, which became the first ABET accredited engineering program in a women's college. The Picker Engineering Program grants a B.S. degree in engineering science and a B.A. in engineering arts. The B.A. degree is designed for students who do not intend to work as professional engineers but who are nonetheless interested in the connection between engineering and broad social issues.

According to Grasso, the founding director of the Picker Engineering Program, a holistic engineering education has to include study of "the human condition, the human experience, [and] the human record." Therefore, the Picker program requires every B.S. student to either complete a minor in a field outside engineering and science or to fulfill the Latin Honors distribution requirements, i.e., to take at least one course in each of the seven fields: the arts, foreign language, historical studies, literature, natural science, mathematics and analytic philosophy, and social science.[32] This requirement ensures that the engineers who graduate from Picker have substantial breadth of knowledge in the non-technical fields.

Teaching in the Picker Engineering Program resonates with its core values, which emphasize applying engineering knowledge to real-world challenges, especially challenges of sustainability. Project-based learning characterizes both the introductory and the capstone engineering courses in Picker. These courses also encourage students to explore the professional, social, and environmental contexts of engineering tasks. In addition to formal, classroom-based learning, students at Smith also practice sophisticated engineering problem solving through collaborating with faculty in research or participating in student clubs. For example, the local chapter of Engineers for a Sustainable World, a student-run engineering outreach club, organizes a variety of projects that engage students, faculty, and community stakeholders.

The Product Design and Innovation program at Rensselaer Polytechnic Institute was founded in 1999, first as a dual-degree program between the Mechanical Engineering and Science and Technology Studies. Over the years, it has evolved into a series of interdisciplinary Programs on Design and Innovation (PDI). Housed in the Department of Science and Technology Studies, an interdisciplinary social science department, PDI attracts students from various engineering disciplines as well as business and communication majors. Unlike the engineering programs at Harvey Mudd and Smith, the design program at Rensselaer is not in itself an ABET accredited engineering program; instead, it offers a social science degree in Design, Innovation, and Society. Meanwhile the program is organized in ways to accommodate PDI students to complete a second full degree in another discipline (mostly in engineering) within four years of study. At present, the majority of PDI students are pursuing a B.S. in Mechanical Engineering and a B.S. in Design, Innovation, and Society.

The PDI curriculum features a series of up to eight design studio courses. Instructors of the studio courses come from engineering, science and technology studies, communication, and management. Faculty members from different disciplines co-teach several studios. In every studio course, students go through one or more complete design processes, from generating design ideas to making and testing prototypes. While all the design studio courses emphasize the synthesis of technical, social, and aesthetic considerations, each studio focuses on a particular aspect of design, such as product development, industrial design, user-centered design, and entrepreneurship. Besides the studio courses, the PDI curriculum also includes courses that explore the relation between design, society, and cultures.

PDI demonstrates the integration of engineering and the liberal arts through the studio-based design pedagogy. In order to design technically feasible and socially acceptable products and service, students combine the methods and tools from a variety of disciplines, such as design thinking (e.g., mind-mapping), engineering technology (e.g., Arduino), and cultural studies (e.g., ethnography). In contrast to the focus on problem solving in typical engineering classrooms, teaching in PDI emphasizes problem finding. PDI students usually start their design projects by studying the relevant objectives and constraints from rich and heterogeneous real-world context, such as the shortage of food and clear water in underdeveloped regions and the stagnation of public schools in American cities. Students also critically analyze the social implications of the problems and design solutions throughout the design process. Some PDI instructors also encourage students to form their own design identities by reflecting on their learning experiences.

Our comparison in this section is an asymmetric one: the cases we select in China are comprehensive universities with a focus on science and engineering, whereas the cases in the U.S. are programs that are explicitly committed to the integration of engineering and the liberal arts. With this distinction in mind, one would note that the general education programs at

Tsinghua and BIT are offered to all undergraduate majors on campus, whereas the programs of liberal arts education at Harvey Mudd, Smith, and Rensselaer are specifically designed for engineering students. The allocation of curricular space for general education in Chinese universities is also affected by the Ministry of Education Compulsory courses. As a result, engineering students at Tsinghua and BIT have fewer credits for electives in the humanities, social sciences, and arts than their peers at Harvey Mudd, Smith, and Rensselaer. However, with the exception of PDI at Rensselaer, the responsibility of educating engineering students in the liberal arts falls largely onto faculties in the humanities, social sciences, and arts in both countries. Both Chinese and American universities are in need of institutional structures for faculties in engineering and the liberal arts to coordinate their educational activities.

Section Three: Challenges Facing Liberal Educators for Engineers

Measured by the quantity and format of programs, general education has made significant progress in Chinese universities and colleges over the past two decades. However, scholars who study general education in China have raised concerns about the prospect, intellectual depth, and coherence of such programs.[33] To begin with, a widespread instrumentalist view of education poses a major challenge for the development of high quality general education. The instrumentalist understanding prevents both educators and students from appreciating and seriously exploring the values of a general education. Influenced by decades of dominance of specialized education, a lot of university professors and administrators consider general education as mere complement to the study of majors. According to this view, the objectives and design of general education programs should focus on better preparing students for specialized studies.[34] Meanwhile, a great number of Chinese students (sometimes pressured by parents) are anxious to develop marketable skills in college; this anxiety often leads them to focus excessively on vocational training at the expense of broad learning in the humanities, social sciences, and arts. Delivering general education through free electives also confronts a number of limitations. For example, engineering departments not only manage about half of the courses on the curriculum but also "own" the students who major in engineering disciplines. Thus engineering faculty members have a natural advantage in shaping the curriculum and attracting students' attention. Lack of such close institutional affiliation with the students, general education often plays a marginalized role. It is not a secret that many college students sign up for general education electives without serious intellectual commitment. Instead, they expect curious, entertaining, and cursory engagement with non-technical contents that will spice up their otherwise stressful and boring studies in their majors. Besides, letting students take random electives fails to convey to them coherent intellectual frameworks that characterize the true value of a general education.

Similar challenges have been encountered by liberal educators in the U.S. One of these challenges relates to Hu and Cao's distinction between a liberal education and a liberal arts education.[35] As Riley points out, programs of educating engineers in the liberal arts often focus on "distribution;" i.e., to expose engineering students to a variety of contents that are usually dealt with in the liberal arts disciplines.[36] This approach does not recognize that disciplines like philosophy, literature, sociology, and art history convey not only content knowledge but also systematic ways of knowing and analyzing the world, ones that are unfamiliar to students who are used to the engineering ways of knowing. Ideally, a liberal education should "liberate" students by enabling them to examine their own worldviews and epistemological standpoints. In American engineering schools, however, this kind of epistemological reflection is all too often overshadowed, if not prevented, by the powerful ideological and epistemological commitments passed down from the engineering profession.

The professional control of engineering education is a powerful drive, and yet another daunting challenge, for educating engineers as liberal learners. A close look at the discussions about liberal arts education for engineers reveals that the conversation is primarily driven by the needs and desires of the engineering profession. In other words, a broad education in the liberal arts is often linked with answers to what types of engineers are needed (e.g., more diverse origins), what engineers need to do in the future (e.g., work in multidisciplinary and cross-cultural settings), and what engineers aspire to become (e.g., a more respected profession, probably with a starting degree at the master's level). This contrasts with movements in higher education that start with what students know and what learning theories say about the best strategies to facilitate learning.[37] Therefore, we argue that liberal arts education for engineers in the U.S. serves primarily narrow, instrumental objectives of the engineering profession. Liberal educators in engineering should strive for the empowerment of students and "prepare[ing] them to deal with complexity, diversity, and change" not only in the professional context but also in the broader terrain of personal and civic life.[38]

Conclusion

In this paper, we seek to inspire a cross-cultural conversation about enhancing engineers' global competencies through a liberal arts education. We compare the objectives, strategies, and challenges of a liberal arts education for engineers in China and the U.S. The bi-national comparison indicates that efforts to educate engineers in the liberal arts are shaped by a mixture of economic, ethical, governmental, and professional factors. We argue that a cross-cultural conversation would generate helpful lessons for educators to broaden engineering students' learning. For example, our case studies suggest that a general education program for all undergraduate majors (in the cases of Tsinghua and BIT) might help with sharing teaching resources in the humanities, social sciences, and arts, but a one-size-fits-all program might fail to convey a coherent framework of liberal learning. Instead, the case of PDI at Rensselaer showcases a promising way to create meaningful integration, with a learning experience designed specifically for the engineering majors.

Moving forward, we suggest that a global community of liberal educators for engineers would further enrich and benefit this realm of effort. For example, with the Bologna Process, European universities have become closer to the ideal of having the five-year master's degree as the starting degree for professional engineers.[39] Presumably this will bring about opportunities to include more liberal arts courses in the five-year engineering curriculum. As president of the Associate for American Colleges and Universities Schneider notes, some Bologna countries are already pursuing more integrative learning for their college students. However, Schneider also points out that universities and colleges in the U.S. have updated the meaning of general education "as a strategy for teaching students how to set their particular interests in larger contexts and how to integrate and apply their learning at progressively higher levels of efforts and achievement."[40] These updates ought to inspire continued discussions for educators in Europe and elsewhere on questions like how to take advantage of the opportunities generated by the Bologna Process, and how does a five-year curriculum work in enhancing engineering students' intellectual and practical capacities.

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[10] This usage contrasts with the meaning of the liberal arts (*artes liberals*) in the Middle Ages, which refers to grammar, rhetoric, logic, geometry, arithmetic, music, and astronomy. See http://www.britannica.com/topic/liberal-arts.

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[13] Li, M. and Shi, H. 2013. "The Impacts of Liberal Arts Education on Undergraduate Programs: Fulfillment or Frustration?." In *General Education and the Development of Global Citizenship in Hong Kong, Taiwan and Mainland China: Not Merely Ice on the Cake*. Edited by Xing, J. Ng, P. and Cheng, C. Routledge.

[14] Bucciarelli, L. 2011. "Bachelor of Arts in Engineering." Unpublished manuscript.

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[17] Historians find that the focus on social responsibility entered the professional discussion much later, mostly after the World War II and during the 1970s. For example, see Mitcham, C. 2009. "A Historico-ethical Perspective on Engineering Education: From Use and Convenience to Policy Engagement." *Engineering Studies* 1:1, 35-53. Also see Tang, X., and Nieusma, D. 2015. "Institutionalizing Ethics: Historical Debates Surrounding IEEE's 1974 Code of Ethics." ASEE Annual Conference.

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[19] Kabo, J., Tang, X., Nieusma, D., Currie, J., Hu, W., and Baille, C. 2012. "Visions of Social Competence: A Cross-cultural Comparison of Engineering Education Accreditation in Australia, China, Sweden, and the United States." OP. cit.

[20] Li, M. and Shi, H. 2013. "The Impacts of Liberal Arts Education on Undergraduate Programs: Fulfillment or Frustration?." Op. cit.

[21] Hu, X. and Cao, L. 2013. "Meaning and Methods: Some Thoughts on the Role of General Education and Curriculum Design." Op. cit.

[22] "Educational Plan for Prominent Engineers" [*zhuo yue gong cheng shi jiao yu pei yang ji hua*]. Tsinghua University. http://www.tsinghua.edu.cn/publish/jwc/7345/.

[23] http://www.bit.edu.cn/gbxxgk/gblsyg/index.htm.

[24] Chen, H., Shen, W., and Cai, L. 2012. Toward general education in the global university: The Chinese model. In A. Nelson and I. P. Wei (eds.), *The Global University: Past, Present, and Future Perspectives* (p.185). New York: Palgrave Macmillan. See also Pang, H., and Huan, X. 2016. "General Education in China: Review and Expectation." *Journal of Higher Education Management*, 10:1. Our discussion here is based on the current plan for general education at BIT. A new plan for general education at BIT will be implemented in Fall 2016.

[25] Pang, H. 2006. "The Localization of General Education in China: Practical Models of General Education at Beijing Institute of Technology." *University General Education*, 1, 119-125.

[26] Ibid.

[27] Ibid.

[28] For the distribution of technical and social related competencies in EC 2000, see Kabo, J., Tang, X., Nieusma, D., Currie, J., Hu, W., and Baille, C. 2012. "Visions of Social Competence: A Cross-cultural Comparison of Engineering Education Accreditation in Australia, China, Sweden, and the United States." Op. cit. It is worth noting that this roughly equal distribution is very likely to change with the ongoing movement to revise the student learning outcomes in the ABET accreditation criteria.

[29] In fact, the implementation of liberal arts education in engineering schools has been the target of critique and reform for more than a century, see Silbey, S. 2015. "The Elephant in the Room: Constraints and Consequences of a Four-year Undergraduate Engineering Degree." *Engineering Studies*, 7:2-3, 164-167.

[30] https://www.hmc.edu/hsa/.

[31] See Harvey Mudd Mission Statement (https://www.hmc.edu/about-hmc/mission-vision/). Over the years, the precise distribution of class hours has shifted, in part because biology and computer science were added to the Common Core curriculum. The humanities, social sciences, and arts take about a quarter of the course credits at present.

[32] http://www.smith.edu/registrar/registration_honors.php.

[33] Pang, H. 2010. "Challenges and Solutions to the Development of General Education Curriculum." *Jiangsu Higher Education*, 2, 63-66. Li, M. and Shi, H. 2013. "The Impacts of Liberal Arts Education on Undergraduate Programs: Fulfillment or Frustration?." Op. cit. Hu, X. and Cao, L. 2013. "Meaning and Methods: Some Thoughts on the Role of General Education and Curriculum Design." Op. cit.

[34] Pang, H. 2010. "Challenges and Solutions to the Development of General Education Curriculum." Op. cit. Pang, H., and Huan, X. 2016. "General Education in China: Review and Expectation." Op. cit.

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[37] Duschl, R., Maeng, S., and Sezen, A. 2011. "Learning Progressions and Teaching Sequences: A Review and Analysis." *Studies in Science Education*, 47:2, 123-182.

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