Gaps, Resources, and Potentials for Growth in Comparative Engineering Education Research

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Published in:
International Handbook of Engineering Education Research

DOI (link to publication from Publisher):
10.4324/9781003287483-4

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

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Gaps, Resources, and Potentials for Growth in Comparative Engineering Education Research

Xiaofeng Tang, Jennifer M. Case, and Andrés Felipe Valderrama Pineda

1 Introduction

The international mobility of the engineering workforce has attracted the attention of policymakers, business leaders, and educators for decades (Committee on Prospering in the Global Economy of the 21st Century, 2007; Bourn & Neal, 2008). Recent challenges on the global stage, such as the COVID-19 pandemic, tensions among major geopolitical powers, and pressing climate crises, underscore the role of engineers in fulfilling national and international needs. These global developments require engineering educators to stay informed of ideas and practices of educating engineers in different parts of the world, mindful of the political, social, economic, and cultural dynamics of different countries. Notably, national ambitions for strengthening the domestic engineering workforce are all reshaping the global landscape of engineering education.

In this chapter, we argue that researchers in engineering education are confronted with crucial needs and great opportunities to generate knowledge about global engineering education by engaging in comparative studies. We define "comparative" as studies that involve more than one country and use the country as the unit for analysis (Turner, 2019). A comparative approach can help researchers develop a more grounded understanding of the global transmission and adaptation of ideas about engineering teaching and learning. International comparisons also test and reveal the limitations of taken-for-granted assumptions of education that have been unproblematized in the Western context (Carnoy, 2019). Furthermore, comparative work can facilitate the growth of an international community of engineering education research (EER). We suggest that comparative studies of engineering education will be enriched by drawing conceptual and methodological frameworks developed in the field of comparative education.

The rest of the chapter is structured as follows. The remainder of this section presents the needs and values of comparative studies of engineering education. To assist researchers who are interested in beginning comparative work, the next two sections introduce the brief history of the field of comparative education and three main approaches developed in that field. We then survey recent comparative EER published in three languages: English, Chinese, and Spanish. Exemplar studies in EER illustrating the application of each one of the three approaches of comparative education are discussed. The following section lays out the strengths and limitations of the three main approaches of comparative education in studying engineering education. The subsequent section discusses

DOI: 10.4324/9781003287483-4

potential contributions to be achieved through engaging comparative perspectives in EER. We conclude this chapter by calling for researchers interested in the global scope of engineering education to proactively embrace comparative work.

Before proceeding with our analysis, we briefly present our positionalities. The three authors are all transnational in their academic experiences: one is of Chinese origin who recently accepted a position in a Chinese university after studying and teaching in the USA for 12 years, one taught in her native South Africa for decades before accepting an academic position in the USA, and the third one is a Colombian scholar with graduate degrees from European institutions and currently holding a position at a Danish university. Two elements of the authors' experiences are related to the analysis presented in this chapter. First, all three authors have experienced and observed universities in our home as well as other countries gravitate toward, and sometimes look up to, the US models of engineering education, including ways of administering programs and curricula and structures of accreditation informed by ABET. Second, our personal experiences also taught us the importance of considering local context in making sense of engineering education policy, contents, and methods, despite the appearance of "global isomorphism" (Klassen & Sá, 2020). Consequently, we were struck by the limited availability of high-quality comparative studies in the current engineering education literature, an endeavor we consider critical in understanding engineering education in various local contexts.

1.1 Moving Out of the National Silo

Several global developments have made comparative research of engineering education both more feasible and imperative. Firstly, the influx of international students in countries with renowned engineering education systems opens questions about engineering education in these students' countries of origin. This is worth noticing when a significant portion of international students in engineering are graduate students who have completed undergraduate training at home (Granovskiy, 2018). The literature on this topic tends to focus on accommodating and supporting international students in the host countries, whereas few studies examine the national systems of engineering education that produced them (Zhu & Cox, 2015). Secondly, as many engineering programs aspire to produce graduates for multinational corporations and/or cross-cultural teams, the teaching of foreign languages and cultures, along with topics like globalization, has become increasingly available in engineering programs. However, publications in the realm of "international engineering education" seem to focus primarily on pedagogical and organizational strategies that assist with students' cultural exchange (abundant examples can be found in the *Journal of International Engineering Education*); they tend to be less focused on investigating systems of engineering education in different national or cultural contexts.

Engineering educators tend to focus on the immediate concerns in their domestic contexts rather than the historical and spatial dimensions of engineering education as a globally connected enterprise, topics that tend to attract the attentions of historians. The history of cross-national influences on engineering education goes back to the colonial period when nations prioritized the production of engineers for colonial expansion and economic gain (Pedrosa & Kloot, 2018). While the training of engineers was directly governed by many local and national governments because of its importance for national and regional security and economic development, cross-national exchanges of ideas and models of engineering education have played a significant role throughout history, with French – and, to a lesser extent, German – models assuming earlier international leadership, which were then succeeded by British and American models in the 19th and 20th centuries, as newly independent nations sought to create their own systems of engineering education (Karvar, 1995; Reynolds & Seely, 1993).

Since the 1990s, significant changes have taken place in the global landscape of engineering education, caused in part by massive growth in engineering enrollments in emerging economies, most notably the economic powerhouses in the BRIC countries – Brazil, Russia, India, and China. In 2009, the total enrollment of engineering students in the BRIC countries was 75% more than the total of engineering students in the USA, Europe, South Korea, Japan, and Australia, countries that up to the 1990s had clearly dominated global engineering education (Loyalka et al., 2014). Meanwhile, international agreements for engineering education accreditation have driven global convergences in how engineering education is governed throughout the world (Case, 2017; Klassen & Sá, 2020).

The field of EER has grown against this backdrop of the worldwide increase in engineering enrollment and global convergences in the governance and practice of engineering education. Interests in improving the national quality of engineering education – a key mission that propelled the birth and growth of EER in many countries – are catalyzed by widely perceived urges to stay ahead in intense competitions of technological innovation, engineering workforce, and higher education in the global market (Lucena et al., 2008; Cao et al., 2021). However, when measured against the goal of devising globally competitive engineering education, most engineering education researchers do not seem to focus much on their "competitors" abroad; thus, published studies of engineering education are mostly conducted within a single national context, usually that of the main author's country of residence.

Besides the pragmatic concerns noted earlier, the scarcity of systematic comparison of engineering education in multiple national and cultural contexts, in our view, indicates missed opportunities to deepen reflections on engineering education in the researchers' own countries and to increase the impact of EER in broader intellectual communities. Here the metaphor "the fish can't see water" serves as a relevant methodological reminder for educational research, as the robustness of theoretical insights derived from education in a single national context often necessitates triangulation with similar educational phenomena in other nations characteristic of different political, economic, and cultural dynamics. For example, it has been pointed out that the famous US sociologist of higher education, Burton Clark, was able to present an influential and convincing interpretation of the key features of US higher education only after his earlier comparative research of other higher education systems (Välimaa, 2008). A similar case might be made with the famous *Wickenden Report* published by the American Society for Engineering Education (ASEE), formally titled "A Comparative Study of Engineering Education in the United States and Europe" (Wickenden, 1929), which made influential arguments about US engineering education by comparing it with European systems.

To scholars who are keen to reflect on the aims and approaches of EER, an important strength of the comparative approach is thus its ability to interrogate – through revealing and comparing different practices – the "blind spots" in one's native system. For example, Western educational researchers have come to think quite differently about the distinction between deep and surface approaches to learning thanks to studies of high-performing students in China who extensively utilized memorization for learning (Kember, 2016). This revealing function makes comparative research a potent vehicle for engineering education researchers seeking to question underexamined notions, such as "evidence-based" education (Riley, 2017). Similarly, notions of diversity, equity, and inclusion that are emphasized by many engineering education researchers in North America and Europe might be enriched by the insights of educators, students, and researchers in Africa, Asia, and South America through a comparative lens. Perhaps more importantly, studying engineering education through a comparative lens has the potential to generate profound understandings of the relationship between engineering education and broader societal parameters, understandings that are of interest not only to engineering educators but also to a broader range of scholarly communities concerned about education and society. After all, the education of engineers is intimately connected to society, especially to the engineering profession, and the structural and cultural shape of these connections will vary from country to country.

To illustrate these arguments further, we briefly unpack a rare example of a rich comparative study in the engineering education literature. The exemplar study, titled "Competencies Beyond Countries: The Re-Organization of Engineering Education in the United States, Europe, and Latin America," was published in the *Journal of Engineering Education* and authored by a team with cross-national and interdisciplinary expertise in history, cultural anthropology, and engineering education (Lucena et al., 2008). The study investigates visions of engineering competency in different countries and regions, as well as how these visions were or were not actualized in standards of engineering accreditation. Unlike many other cross-national/regional comparisons of engineering accreditation systems, Lucena et al. (2008) do not focus on listing student outcomes in various accreditation standards. Instead, the article centers on a more analytical question: Why is it that similar attempts to create a unified, outcome-based engineering accreditation system succeeded clearly in the USA and partially in the European Union yet failed in Latin America? The authors did not take for granted the success of the US accreditation system, nor did they assume the "correctness" of the US model simply because ABET achieved domestic and international success in promulgating outcome-based criteria for accreditation. Seeking a more grounded interpretation of the cross-national/regional differences, Lucena et al. (2008) inquire into the historical processes and institutional dynamics that produced success in certain cases and failures in others and, in this process, reveal structural features that account for differing receptions of a similar – and globally converging – idea for assessing engineering education, that is, outcome-based education.

Lucena et al. (2008) illustrate several strengths of comparative studies of engineering education. First, the study demonstrates that the meanings of engineers' global competency depend on national priorities, which are reflective of domestic economic needs, the status of industrial development, and the political inclinations of the engineering profession. Second, the study shows that efforts to reform engineering education are in important ways mobilized or constrained by the interplay between governments, businesses, professional organizations, and engineering educators. These lessons remind us that key concepts embraced in the US-based EER community, such as outcomes, evidence, and readiness, are the likely results of negotiations among stakeholders in specific discourses of engineering education. Hence, comparative perspectives should not only help engineering education researchers stay informed of foreign practices but also enhance their ability to generate more grounded theories of engineering teaching and learning by extending the scope of analysis to encompass such negotiations. Lucena et al. (2008) also showcase how comparative research of engineering education can contribute to a broader understanding of education and society. While the ABET EC2000 reform and the Bologna Process indicated the ambitions and readiness of the USA and the European Union to embrace a globalized engineering workforce, the unsuccessful bid for accreditation in Latin America reflected political fragmentations in the region, where competing national agendas slowed down regional integration. The comparison of engineering accreditation systems in this study thus provided a compelling case for the uneven globalization of higher education.

2 Comparative Education: A Brief History

The field of comparative education has developed vibrant intellectual communities and solid research infrastructure since the mid-20th century, whereas the origins of the field vary by different accounts. Many scholars consider the publication of French official Marc-Antoine Jullien's *Plan and Preliminary Views for a Work on Comparative Education* in 1817 as the beginning of comparative education (Manzon, 2011). In their book *Toward a Science of Comparative Education*, Noah and Eckstein (1969) sketch the history of the field in five stages. The first stage consisted of "travelers' tales" that incidentally reported the status of education in foreign countries. In the second stage, emissaries were sent by governments to intentionally study education abroad, seeking useful ideas and practices that might be borrowed to improve education at home. The activities in the third stage similarly consisted of sending visitors abroad, but the purposes for the visits were less concerned with borrowing educational ideas than building understanding and collaboration across countries. During the fourth stage, scholars of comparative education went beyond documenting foreign educational phenomena to investigating deeper political, social, and cultural dynamics that shape education in the target countries. During the fifth stage, the now-established field of comparative education, following the examples of more established social sciences, like economics and sociology, embarked on the process of reinventing itself as a science.

Noah and Eckstein's hope for a science of comparative education was echoed by several influential comparativists in the 1950s and 1960s, including Bereday, Holmes, and King. Bereday introduced a structured process of comparing education "through stages of description, juxtaposition, analysis, and interpretation" (Turner, 2019, p. 14). The enthusiasm for the science of comparative education during this period was partly fueled by North American scholars' training in quantitative techniques and their belief in positivist epistemologies, which hold that one can discover general laws of the relationship between education and society by comparing data from different countries. In the 1970s and 1980s, the strong influence of positivism on comparative education dimmed as more critical Marxist and neo-Marxist perspectives took over the spotlight. Carnoy's studies of education and income in different countries during this period laid the foundation for the argument that education serves as a cultural instrument for wealthy countries, many of whom were former or present colonizers, to keep the colonized and economically exploited countries at bay (Carnoy, 2019). Within countries that gained independence recently, Carnoy further points out, access to education serves to retain the concentration of power and resources among social and economic elites. Since the 1990s, the field of comparative education has entered a stage of "heterogeneity" that witnesses the co-existence of multiple standpoints and methodological traditions. The increasing impact of globalization has also driven some scholars to study education systems that transcend national borders, while others, inspired by postmodernism and post-structuralism, focus on comparing local educational practices instead of pursuing grander, national-level narratives (Manzon, 2011; Turner, 2019). As Turner (2019) puts it, the comparativists "have come to accept that there may be many ways of conducting research in comparative education" (p. 25).

3 Major Approaches in Comparative Education

Given the heterogeneity of objectives, standpoints, and methodological traditions in the field, any attempt to classify the major "approaches" of comparative education is likely to encounter justified opposition. This section presents one of such imperfect classifications as an entry point for interested engineering education researchers. Amid the succeeding, overlapping, and co-existence of multiple traditions of comparative education, three main approaches have endured since at least the 1950s, each characterized by somewhat-distinct purposes, epistemologies, and methods (Manzon, 2014). The first one might be termed a "scientific" approach. As Noah and Eckstein (1969) suggest, the scientific approach of comparative education attempts to produce generalized laws about education and society. Supported mainly by positivist epistemologies, the scientific approach emphasizes hypothesis-testing using cross-national, quantitative data, such as years of schooling, learning achievements, and income of graduates. The second approach might be called "ameliorative," which finds its predecessors among the educational emissaries in the 18th and 19th centuries. Inspired primarily by pragmatic epistemologies, the ameliorators seek to identify the best policy and pedagogical practices that can be borrowed to improve education in their home countries. Methods favored by the ameliorators range from content analysis of policy to qualitative and quantitative analysis of instructional strategies. A third, "interpretive," approach is often endorsed by the humanist traditions of educational research, which seek to understand the cultural and social contexts behind educational phenomena. The underlying epistemologies for the interpretive approach are influenced by cultural relativism. The interpretivists often use qualitative methods, like ethnography, for unpacking deeper cultural meanings of educational practice. In the remainder of this section, we illustrate each approach with a well-recognized study in the field of comparative education.

3.1 PISA Scores and National Economic Growth: An Illustrative Case for the Scientific Approach

The rise of large-scale international surveys and tests provided powerful support to advocates of the scientific approach of comparative education, who seek to test hypotheses with multinational data. Since the 1960s, the International Association for the Evaluation of Educational Achievement (IEA) has played a significant role in advancing scientific comparison of educational achievement across countries. Beginning in 1997, the OECD's Programme for International Student Assessment (PISA) has become another powerhouse for comparing educational performance through standardized tests.

The OECD report "The High Cost of Low Educational Performance: The Long-run Economic Impact of Improving PISA outcomes" exemplifies a scientific approach to predicting the relationship between national economic growth and the cognitive skills of its workforce (Hanushek & Woessmann, 2010). In this study, Hanushek and Woessmann sought to accurately portray the relationship between economic growth and educational achievement, replacing outdated metrics like average length of schooling with more precise measurement of the cognitive skills of national workforce, which was calculated from PISA scores. The resultant modeling produces (alluring) predictions of potential economic growth that can be gained from improving the education of the workforce: a boost of average PISA scores by 25 points among OECD countries can result in a net gain of 115 trillion dollars in accumulative growth in GDP.

3.2 Curriculum Standards from Top-Performing Countries: An Illustrative Case for the Ameliorative Approach

Schmidt et al.'s (2005) study of curriculum coherence exemplifies the focus of the ameliorative approach on discovering best practices of education in foreign countries. The study was motivated by US educators' concerns for the lack of coherence among national, state, and local curriculum standards, namely, that eclectic political processes in the USA resulted in curricula that looked like arbitrary "laundry lists" instead of well-organized systems of knowledge (Schmidt et al., 2005). To demonstrate more coherent ways of setting curricula, Schmidt et al. (2005) analyze curriculum standards from top-performing countries and regions in the Third International Mathematics and Science Study (TIMSS). The study finds that mathematics standards in the TIMSS top-performing countries and regions demonstrated clear and logical progression of knowledge, beginning with simpler, more foundational content in the lower grades and gradually developing into more complex content in the higher grades. This way, suggested the authors, learning in the earlier years builds the foundation for students to tackle more complex mathematics as they proceed in the curriculum. In comparison, the US mathematics standards showed less logic: most topics were covered from grade 1 to grade 8, leading to possible repetition and limited depth in student learning (Schmidt et al., 2005). The US science curriculum standards showed a similar lack of coherence when compared with those adopted by the top performers in TIMSS. While the latter introduced different scientific topics at different stages, Schmidt et al. (2005) notice an "absence of a clear pattern" (p. 551) in the US science standards.

Based on the cross-national comparison, Schmidt and colleagues made two suggestions for improving curriculum standards in the USA. First, the authors suggested enhancing the role of disciplinary specialists, such as university professors and mathematicians, in shaping curriculum standards. In a second – and bolder – suggestion, Schmidt et al. (2005) propose the relinquishment of state and local standards, arguing that "coherence and rigor might only be possible in the US if curriculum standards are national in scope" (p. 556).

3.3 Preschool in Three Cultures: An Illustrative Case for the Interpretive Approach

"The research methods used [should be] sufficiently searching to probe beyond the observable moves and counter-moves of pedagogy to the values and meanings which these [moves] embody" (Alexander, 2000, p. 266). This quote characterizes the gist of the interpretive approach of comparative education, which is also exemplified in *Preschool in Three Cultures: Japan, China, and the United States*, a seminal comparative study of early childhood education (Tobin et al., 1989). The authors termed their method "multivocal ethnography," with which daily operations of preschools in Japan, China, and the USA were videotaped by the research team, and the videos were subsequently viewed and commented, in turn, by insiders (administrators, teachers, parents, and students) affiliated with the featured preschools and by other parents, preschool teachers, and education researchers from each of the three countries. Through juxtaposing preschool practices in different countries and commentaries on these practices by multicultural audiences, the authors created a "dialogue" that revealed culturally specific ideas about education. For example, after watching scenes of a "difficult" child in a Japanese preschool who frequently challenged authorities and engaged in aggressive behaviors, many Chinese and American viewers expressed concerns over the teacher's failure to intervene. However, the supervisors and teachers at the Japanese preschool featured in the video approved of the teacher's non-provocative choices as pragmatic.

Beyond reporting views and practices of preschool in different cultures, Tobin et al. (1989) produce profound theoretical insights by probing the socioeconomic contexts lying behind the multicultural views and practices. The book argues that underneath differing approaches to educating young children in three countries was a similar motivation to prepare children as members of "low-fertility, educationally competitive, industrial societies" (p. 197). The authors pointed out that the evolution of economic relationships in urban China, Japan, and the USA made it difficult to pass down material wealth to the next generation, leading parents to invest instead in the cognitive and emotional development of children. The authors also noted distinctive ways in which members of different cultures reacted to the intense parental attention placed on children because of low fertility rates; in other words, in societies where birth rates are low, the average parental attention on a child is expected to rise accordingly (Riley, 2018). While the consequential promotion of children's individuality and ego was well accepted in the American culture, Chinese parents reacted ambivalently to these changes, being sensitive to the tension between children's individualistic development vis-à-vis collectivist cultural values in Chinese society.

4 A Survey of Comparative Engineering Education Research: 2010–2020

This section surveys the status of comparative engineering education research published in English, Chinese, and Spanish in the decade between 2010 and 2020. The time range was chosen to complement the *Cambridge Handbook of Engineering Education Research*, which was published in 2014. Although the *Cambridge Handbook* does not include a chapter explicitly dedicated to comparative research, several chapters in the handbook (e.g., "Global and International Issues in Engineering Education") take note of varying institutional structures and styles of engineering teaching and learning in different countries. Therefore, our survey seeks to present more recent developments in comparative studies of engineering education. The choice of surveying publications in three languages used by most of the world's population indicates our attempt to exercise the spirit of comparatists, namely, to read and compare scholarly works in different cultural communities (indicated by the language of publication) as a way to understand the respective priorities, educational contexts, and intellectual approaches characteristic of EER in different parts of the world.

For works published in English, we used the search string [(comparative OR cross-national) AND "engineering education"] in Web of Science, in addition to manually screening the titles of all the articles published in the *Journal of Engineering Education* and *European Journal of Engineering Education* during this period. For publications in the Chinese language, we used the search string [比较 (comparison) AND 工程(engineering) AND 教育(education)] in cnki.net. For works in Spanish, we reviewed publications in *Revista de Ingeniería* (Colombia), *Revista International de Educación en Ingeniería* (México), and *Revista Iberoamericana de Educación en Ingeniería* (RIEI). The search in Spanish literature was complemented with a wider search on the Internet and through the authors' contacts in the region.

Two inclusion criteria were applied to the initial findings: (1) publications should explicitly address engineering education, and (2) publications should focus on postsecondary education. According to these criteria, publications that treat STEM education as one entity or examine engineering education in the K–12 context were not included in this analysis. The search resulted in 54 publications in total: 25 in English, 25 in Chinese, and 4 in Spanish. A summary of resultant references and the main objects of comparison reported therein is presented in Table 3.1.

Table 3.1 Summary of Comparative Engineering Education Research Published in English, Chinese, and Spanish between 2010 and 2020

Language	*Reference*	*Object of Comparison*
English	Palma et al. (2011); Grenquist and Hadgraft (2013); Bradley (2013)	Accreditation
	Ku and Goh (2010); Gong et al. (2011); Ku et al. (2011); Khattak et al. (2012); Tang and Lord (2012); Lunev et al. (2013); Case et al. (2015); Gardelle et al. (2017)	Curriculum/facilities
	Cerda Suarez and Hernandez (2012); Cao (2015); Holmberg (2016); Santos et al. (2018); Polmear et al. (2019)	Pedagogy/instructor
	Lau (2013); Carr et al. (2015); Duffy et al. (2020)	Learning achievements

(*Continued*)

Table 3.1 (Continued)

Language	*Reference*	*Object of Comparison*
	Lahijanian et al. (2010); Barnard (2012); Kinnunen et al. (2016); Oda et al. (2018); Capretz (2019); Colomo-Palacios (2019)	Student perspectives
Chinese	Ma et al. (2010); Pu et al. (2010); Song et al. (2012); Cui (2013); Li, L., et al. (2013); Li, Y., et al. (2013); Fang (2014); Wang, et al. (2014); Liu and Zhu (2015); Zhang (2016); You et al. (2017); Du et al. (2019); Hu (2020); Wang, et al. (2020)	Accreditation
	Guo and Zhi (2010); Zhao and Lin (2011); Liu (2012); Shen (2013); Feng et al. (2014); Zhu et al. (2015)	Policy/vision
	Wu and Xu (2010); Wang (2016); Zhuang et al. (2020)	Curriculum/facilities
	Luo and Fan (2018)	Pedagogy/instructor
	Zhao and Chang (2020)	Student learning
Spanish	Hamid Betancur & Torres-Madronero (2015)	Accreditation
	Zartha Sossa (2013); ASIBEI (2019); Duque & Rangel Espejo (2021)	Curriculum/facilities

4.1 Comparative Engineering Education Research in English

The comparative papers published in English examined a wide range of topics in engineering education. Objects of comparison included accreditation, curriculum, educational facilities, instructors' perspectives, pedagogical choices, student learning achievement, as well as student perspectives on engineering learning.

The growth of international agreements on engineering accreditation – most notably the Washington Accord – has attracted scholarly interest in comparing national accreditation standards and systems (although this body of work in English was less prominent than in the Chinese literature shown next). Researchers also compared curricula of similar programs in different countries, although the samples were usually confined to a limited number of institutions in each country. A significant portion of the comparative studies examines engineering teachers and students, reflecting the focus of EER in North America and Europe. This body of work examines instructors' beliefs and pedagogical choices as well as the abilities, achievements, and perspectives of engineering students. Notably, explicit comparisons of student perspectives appeared only in English literature (and not in Chinese or Spanish literature). Overall, when compared with the extensive body of EER published in the same period, the number of comparative studies was minuscule (Williams et al., 2018). We also note that all the journal publications in English listed in Table 3.1 appeared in the *European Journal of Engineering Education*, while the rest of the English publications appeared in conference proceedings. We found no explicit cross-national comparison of engineering education published in the US-based *Journal of Engineering Education* during this period.

4.2 Comparative Engineering Education Research in Chinese

Driven by a wish to build a strong national system of engineering education, researchers in China have enthusiastically studied best practices from global "leaders," that is, nations and institutions that were considered homes of world-class engineering education. This enthusiasm is echoed in a plethora of publications that examine professional organizations, accreditation standards, engineering curricula, and instructional methods from advanced industrial countries like the USA, the UK, France, Germany, and Japan, as well as renowned engineering institutions like MIT, Cambridge, and École Polytechnique. To assess the status of comparative engineering education research, we limited the scope of our analysis to publications that had an explicit comparative intent, recognizing that there are many more publications in Chinese that report on foreign ideas and practices of engineering education without necessarily comparing them across countries.

Between 2010 and 2020, most comparative studies of engineering education published in Chinese focused on accreditation, as can be seen in Table 3.1 in the preceding section. This topical focus coincided with the emergence and development of engineering accreditation in China: pilot accreditation of engineering programs began in 2006, followed by China's application to join the Washington Accord in 2009 and its acceptance as a full signatory in 2016. The practical need of developing and operating a national accreditation system motivated scholarly investigations of other nations with established accreditation systems. However, the pragmatic urge to understand the standards and procedures of accreditation seemed to overshadow more in-depth analyses of structural factors that gave shape to accreditation systems in various industrial societies (as, for example, seen in the Lucena et al. (2008) study reviewed earlier). Besides accreditation, the comparative literature in Chinese examined policy initiatives and educational visions that drove reforms of engineering education in different countries, along with comparisons of curricula, learning facilities, pedagogical approaches, and student learning.

4.3 Comparative Engineering Education Research in Spanish

We only identified three journal publications in Spanish between 2010 and 2020 that met our inclusion criteria. Hamid Betancur and Torres-Madronero (2015) describe documents and procedures of engineering accreditation in Colombia, Costa Rica, Chile, Mexico, and the USA. Zartha et al. (2013) compare a set of quantitative indicators for 18 institutions of higher education from members of the Organization of American States. Duque and Rangel (2021) report the effort of a university to benchmark its engineering education against programs of similar institutions in other countries. Besides peer-reviewed research publications, the report of Ibero-American Society for Engineering Education (ASIBEI) represented a robust comparison of systems of engineering education in nine Iberoamerican countries: Argentina, Brazil, Colombia, Ecuador, Spain, Mexico, Paraguay, Portugal, and Uruguay (ASIBEI, 2019). This report details characteristics of the engineering curriculum, role of instructors, profiles of prospective engineering students, and graduate placement in member countries of ASIBEI. Common features of engineering competencies across the nine countries are also summarized in the report, making it a rare exemplar of comparative engineering education research that goes beyond superficial analyses of numerical indicators. The report nonetheless surprised readers with its late arrival, given that Lucena et al. (2008) mention the efforts by ASIBEI to create a regional profile 11 years before the appearance of the final report.

Overall, the volume of cross-national comparisons of engineering education published between 2010 and 2020, detailed in this analysis, has been small compared with the total amount of EER works published during this period. The thematic foci of the comparative studies, however, showed some breadth, ranging from macrolevel issues of governance and accreditation, midlevel topics like curricula, to microlevel issues, like instructional choices and student performance. Notably, issues of diversity, equity, and inclusion, which received extensive attention in the EER community during the same period, were not yet reflected in the body of comparative work.

Considering the methods used for comparison, we found that most published comparative studies of engineering education during this period had confined themselves to simply "benchmarking" or "describing" relevant policy, curriculum, and instructional methods, while very few studies were carried out following the major methodological approaches of comparative education. This status of methodological underdevelopment seems to hold EER scholars back from systematically assessing engineering education across countries and from investigating the underlying structural forces that influence international similarities and differences in engineering education. That said, across this survey, we did manage to identify a few studies of comparative engineering education that demonstrated the values and potential of systematically utilizing methods of comparative education. We now turn to illustrate each of these three comparative research approaches with a closer look at selected EER examples that we identified through our survey.

4.4 Comparative Engineering Education Research Using the Scientific Approach

The scientific approach of comparative education was utilized in a few studies that compared the achievement and attributes of engineering students across countries. Zhao and Chang (2020) compare the learning behaviors of engineering students in China and the USA using data collected with two standardized instruments: the Student Experience in the Research University International Consortium (SERU-I) and the University of California Undergraduate Experience Survey (UCUES).

Zhao and Chang intended to characterize engineering students' learning behaviors and to compare these characteristics with those of students in science, humanities, and social sciences. Two forms of comparison were presented in their paper: first, a comparison of engineering students (both Chinese and American) with college students in non-engineering majors; second, a comparison of Chinese and American engineering students' learning behaviors. Due to the fact that the proportion of engineering student respondents was not comparable between the Chinese and American samples, the authors declared that they did not statistically compare the results between Chinese and US students (Zhao & Chang, 2020).

The study compared seven dimensions of learning behaviors, including (1) allocation of study time, (2) reflective learning, (3) team-based cooperative learning, (4) learning through interaction with faculty outside classes, (5) challenge-based learning,[1] (6) class participation, and (7) task completion–based learning (Zhao & Chang, 2020). The authors found that:

- Engineering students in both countries spend more time studying than non-engineering majors. Engineering students in China spend more time taking classes than peers in other majors, whereas US engineering students spend more time studying outside classes in comparison with other majors.
- In both countries, engineering students engage less in learning through reflection, class participation, and task completion than students in humanities and social sciences majors in the same country.
- Engineering students in China participate similarly with other majors in team-based and challenge-based learning, whereas US engineering students are more likely to work in teams than other majors and less likely to engage in challenge-based learning than science majors.
- In both countries, students of all majors score low on learning through interaction with faculty outside classes.

Overall, Zhao and Chang (2020) find no definitive patterns of learning behaviors that characterize engineering students and distinguish them from students in other majors. The authors interpreted this finding from three dimensions. First, most educational objectives in engineering focus on the lower end of Bloom's taxonomy (remembering and understanding), while higher-level skills like analyzing, synthesizing, applying, evaluating, and innovating are underemphasized. Second, drawing from the second author's own educational experiences in Chinese and American universities, the authors suggested that undergraduate engineering curricula in China's research-intensive universities have a clear "theoretical orientation," which leaves limited curricular space for practical learning. This observation was referenced to contextualize the result that engineering students in China spend significantly more time studying inside than outside classes. Finally, Zhao and Chang (2020) suggest that engineering students' inactive class participation in both countries might result in part from the prevalence of traditional, lecture-based modes of engineering teaching.

4.5 Comparative Engineering Education Research Using the Ameliorative Approach

Polmear et al. (2019) explore engineering educators' perceptions of ethics teaching in the USA, non-US Anglo countries (such as Australia and Canada), and across a wide range of Western European countries. The study centers on three key questions, delivered via an online survey. First, a close-ended question inquired whether instructors think students receive sufficient ethics education in their programs, to which the majority responded "no." A second, close-ended question asked the respondents to check off from a list ethics-related topics that were taught in their programs. A third question invited open-ended responses on general issues about teaching ethics to engineering students.

The study was implicitly driven by an ameliorative approach, as the US-based research team sought best practices from international counterparts that could be incorporated into engineering education in the USA. The authors compared responses from US instructors with those from non-US Anglo countries and with those from Western European countries, respectively. The first comparison showed that engineering ethics education in the non-US Anglo countries had greater coverage of macroethics topics, such as environmental protection, sustainability, risk, and practices of the engineering profession, than the US curricula. The authors suggested that the difference might reflect a greater prominence of macroethics topics in the accreditation standards adopted by non-US Anglo countries.

The second comparison showed that the Western European countries taught environmental protection and sustainability more than the US programs did, while making fewer references to topics like professional codes of ethics and safety. To interpret this latter difference, the authors drew on other research to argue that Western European countries, most notably the Netherlands, differed from the "traditional American approach" that focuses on professional codes and instead paid more attention to the social and environmental contexts of engineering as a way to broaden the scope of engineering ethics education.

Notably, the analysis of open-ended responses pointed to a broadly existing consensus among instructors in different countries that engineering students did not get sufficient education in ethics. Polmear et al. (2019) also find that educators across different countries faced challenges in getting students to value ethics education. Accordingly, the authors suggested that ethics should be integrated into technical coursework.

4.6 Comparative Engineering Education Research Using the Interpretive Approach

Zhao and Lin (2011) propose "macro policy systems" as a lens to interpret models of engineering education in different nations. The authors contended that to understand education systems that were designed to produce innovative and practical engineers, one ought not to confine the scope of investigation to colleges and universities but should examine the broader "education system" – ranging from preschool to higher education – and how education is supported by the policy system characteristic of political structures and processes, as well as the relationship between the elite and the mass in each national context. Hence, Zhao and Lin (2011) investigate the relationship between models of engineering education and characteristics of the labor market and social welfare policies in 18 countries and regions across the globe. According to this analysis, Zhao and Lin divided the 18 countries and regions into five models of engineering education:

- The **continental/conservative** model aims to produce a high-quality and practice-oriented engineering workforce through close collaboration between educational and business institutions in countries with proactive social welfare policies. Zhao and Lin (2011) name Germany, France, and Italy as exemplars of this model.
- The **Anglo/liberalist** model, typified by the USA, the UK, Australia, and Canada, prioritizes the education of engineering generalists, highlighted by critical thinking, innovation, and understanding of sociotechnical systems, to meet the demands of market-driven economies.
- The **Nordic/social democratic** model is exemplified by Finland, Norway, Denmark, Sweden, and Switzerland, countries with high levels of human capital and student autonomy. The Nordic/social democratic model of engineering education, as described by Zhao and Lin (2011), emphasizes theoretical learning and academic research for the preparation of high-tech workers.
- The **East Asian** model, seen in Japan, Korea, and Taiwan, stresses the role of engineering in serving national and regional (economic) needs. The authors suggested that the co-existence of Western ideas (e.g., autonomy) and Confucian doctrines (e.g., loyalty) led to a fusion of intellectual freedom and social responsibility in the training of East Asian engineers (Zhao & Lin, 2011).
- Finally, Zhao and Lin (2011) discuss engineering education in **developing countries** (e.g., India and Brazil) that had shared characteristics of industrialization with China. The authors suggested

that engineering education systems in these developing countries were emulated from advanced industrial countries, but these systems had not yet matured into distinctive models of their own.

5 Strengths and Limitations of Three Approaches for Comparative Engineering Education Research

The strengths and limitations of the three approaches of comparative education in the context of EER are summarized in Table 3.2. As we hope to convey in the following paragraphs, there is no one best way to conduct comparative research on engineering education; rather, choices of approaches and methods should be aligned with the purposes of the research. The scientific approach of comparison has the potential to enhance EER in three ways. First, the collection and analysis of multinational data (via surveys and tests) can contribute to understanding international students as well as the distinctive characteristics of domestic students in comparison to international peers. Second, the need to collect and compare data across countries brings about opportunities to form international collaborations. Third, as Zhao and Chang (2020) illustrate, cross-national comparison of engineering and non-engineering students could potentially reveal distinct features of engineering teaching and learning, which lays the groundwork for future research (e.g., studies of the "boundaries" of engineering education across national contexts).

Meanwhile, researchers following the scientific approach in comparing engineering education are confronted by two main limitations. Firstly, comprehensive international data collection can be costly and time-consuming. What is more, unlike in the case of primary and secondary education, at present there is no standardized international test for engineering; thus, international comparisons following the scientific approach are often confined to self-report surveys, which limits the scope and depth of comparison. The second major limitation stems from well-known critiques of the positivist epistemology underpinning the scientific approach: in short, hypothesis-testing based on quantitative data necessitates certain processes of "abstraction" that leave out many meaningful details. For example, the name "engineering degree" means different professional credentials and varying lengths of study in different countries. Variations of this kind are not easily visible in quantitative analysis, which is often favored by the scientific approach.

An important strength of the ameliorative approach is its congruence with existing practices of EER. After all, the improvement of engineering education has been a key driving force for EER, and numerous reports on engineering education in different countries have been produced in the spirit of improving engineering teaching and learning. Given the emphasis placed on the continuous improvement of engineering education in different countries, the ameliorative approach is also likely to enhance the practical relevance of comparative engineering education research. In addition, studies following the ameliorative approach are often driven by specific and focused questions in educational practice, which provide clear guides for the selection of objects for comparison. Hence, this approach is more accessible for researchers who do not have extensive training in comparative education but are familiar with the practical aspects of engineering education.

However, the accessibility of the ameliorative approach is maintained at the cost of methodological consistency. Indeed, improvement can result from many sources, and there is not a clearly delineated framework for conducting comparative research for the amelioration of engineering education. Yet the lack of a consistent methodological framework is likely to confine the research findings to piecemeal recommendations. A second limitation of the ameliorative approach relates to researchers' relatively superficial consideration of the context for implementing the educational practices learned from abroad, when research in engineering education has pointed out that the context of implementation can influence the success of educational innovation as much as the actual focus of the innovation (Litzinger & Lattuca, 2014).

Table 3.2 Strengths and Limitations of Three Approaches for Comparative Engineering Education Research

	Strengths	*Limitations*
Scientific approach	• Understanding students • International collaboration • Inspiring future research	• Cost and feasibility • Positivist epistemology
Ameliorative approach	• Congruence with existing practice • Practical relevance • Focus and accessibility	• Inconsistent methodology • Context of implementation
Interpretive approach	• Grounded-ness • Global trends	• Feasibility and affordability • Knowing why vs. knowing how

A major strength of the interpretive approach of comparative research is its "grounded-ness," that is, this approach not only attempts to describe educational practices in different countries but also seeks to understand and interpret their meanings and implications. Therefore, the interpretive approach helps avoid imposing decontextualized concepts of engineering education to different countries. Grounded interpretations and comparisons of national engineering education systems also reveal overall trends of global engineering education development. This is the second major strength of the interpretive approach.

Of course, it is not an easy task to decode educational culture abroad, which often requires time-consuming and sophisticated training in local knowledge and languages. The feasibility and affordability of interpretive comparison hence form an important limitation. Another challenge for the interpretive approach might be characterized as the conflict between "knowing why" and "knowing how." While the interpretive approach provides culturally relevant interpretations of engineering education policies, structures, and ways of teaching and learning, it is not necessarily easy to derive actions for improving engineering education from these interpretations.

6 Potential Contributions of Comparative Engineering Education Research

This section draws together our findings to argue that comparative studies have the potential to make important contributions to the research, practice, and governance of engineering education in six ways:

1 ***Improving understanding of domestic and international stakeholders.*** Through creating knowledge about policies, engineering teaching and learning, instructors and students, as well as engineering professions and related organizations in different countries, comparative studies help researchers and educators better understand and communicate with stakeholders in engineering education, especially with international faculty and students, and transnational employers that conduct business in the global market.
2 ***Revealing diverse national systems of engineering education.*** Comparative analyses of the various ways in which local political wills, economic imperatives, and cultural norms interact with the processes and outcomes of engineering education help reveal the global diversity of engineering education.
3 ***Providing space and languages for international EER collaboration and exchange.*** The presentation of multinational and cross-national cases creates space, as well as common languages, for researchers in different countries and regions to exchange research strategies, questions,

and findings, thus facilitating a more engaged and inclusive global EER community. Also, the promotion of a comparative research agenda is likely to encourage engineering education researchers to formulate productive collaboration with broader communities of researchers (in comparative education and beyond) who have expertise in cross-national comparison.

4 ***Unpacking international and national governance of engineering education.*** Through global economic and technological exchanges, the impact of domestic engineering workforce preparation is often seen beyond national borders. Meanwhile, the governance of engineering education is deeply rooted in the political and economic dynamics within the national context. Thus, comparative studies help engineering educators better grasp the dynamics between main players (e.g., international organizations, governments, professional organizations, corporations, and educational institutions) that shape the governance of engineering education. Given the strong ties between engineering education and industrial and professional organizations, comparative engineering education research has unique opportunities to produce knowledge about education governance that is not easily available in other domains of (higher) education research.

5 ***Exploring common and unique challenges of broadening participation in engineering education in different contexts.*** Engineering educators in many parts of the world endeavor to recruit students from broader populations than those who have traditionally dominated the profession. Comparative research might shed light on similarities and differences that are characteristic of challenges to broadening participation in engineering in different parts of the world. Whereas the compound challenge of diversity, equity, and inclusion in the USA has motivated some EER scholars to incorporate the concept of intersectionality, in countries like South Africa, Colombia, and Brazil, the challenge also needs to encompass differences in regions and economic status. The entry of immigrants occupies center stage in debates about justice and inclusion in some European countries, and an emerging agenda of gender equity is being explored by engineering educators in China.

6 ***Creating new knowledge on the interactions between engineering (technology) and society around the globe.*** Comparativists often remind us that the systems and objectives of education are shaped by societal expectations. In a time with an expanding and fast-changing global order, comparative studies of evolving notions of engineering competency in different countries would help us appreciate societal expectations of engineering in different parts of the world, and such appreciation lays the groundwork for articulating and assessing the role of engineering in addressing global challenges.

Table 3.3 displays examples in which comparative studies of engineering education reviewed in this chapter contribute to one or several of the potential areas presented in the preceding list. The table shows that existing comparisons of engineering education systems, pedagogies, and learning styles help contribute to understanding of stakeholders, national systems, governance, and societal expectations of engineering education, as well as to intellectual exchanges between international EER scholars. As already noted earlier, the comparative works reviewed in this chapter have not explicitly addressed broadening participation in engineering education.

7 Conclusion

This chapter attempted to demonstrate the untapped potential of comparative studies in engineering education. While exemplar studies show the value of cross-national comparison, our review of recent EER literature in three major publishing languages found a limited number of comparative studies, and thus, there is much scope for enhancing and expanding this body of work. Considering the present availability of online tools for surveys and interviews, it is unlikely that difficulties in accessing multinational data are the major impediment to comparative research. Instead, we suspect

Table 3.3 Contributions of Comparative Engineering Education Research Illustrated by Studies Reviewed in This Chapter

Potential Contribution of Comparative Engineering Education Research	*Illustrations from Studies Reviewed in This Chapter*
A. Understanding stakeholders	Polmear et al. (2019) contribute to the understanding of engineering instructors in the USA and in European countries. Zhao and Chang (2020) contribute to the understanding of engineering students in China and the USA.
B. Diverse national systems	Lucena et al. (2008) show how international practices and standards influence engineering education in Europe and America. Zhao and Lin (2011) exhibit how the global landscape of engineering education is enriched by different "styles" of economic, welfare, and professional policies.
C International collaboration and exchange	Polmear et al. (2019) and Zhao and Chang (2020) use standardized survey instruments that enable the comparison of multinational data on engineering teaching and learning.
D. Education governance	Lucena et al. (2008) and Zhao and Lin (2011) reveal characteristics of engineering education governance across different nations, regions, and cultures.
E. Broadening participation	N/A.
F Engineering and society	Lucena et al. (2008) demonstrate how conceptions of engineering competency are contextualized in geopolitical dynamics and national economic structures.

that the limitation might be attributed to the self-identity of the EER community, which often focuses on issues bounded in a national context, due in part to the priorities of funding agencies and academic journals. However, we contend that an excessively inward-looking research agenda might hamper the capacity of researchers' national systems of engineering education when knowledge of alternative ways of organizing and delivering engineering teaching and learning is lacking.

To assist engineering education researchers to engage in more systematic comparative work, we have provided an overview of the field of comparative education and introduced three major approaches that are often used in that field. Each of the three approaches has been applied in EER and, in each case, has generated productive findings. However, if EER aims to be a truly global field of scholarly pursuit, a comparative perspective is going to play a much more significant role than it currently does, assisting in engineering educators' appreciation and reflection on the opportunities and limitations present in their locations.

Note

1 Challenge-based learning in Zhao and Chang (2020) refers to student learning through addressing academically challenging tasks. The related survey items examined students' willingness to select academically challenging courses and projects, sometimes at the expense of their grades.

References

Alexander, R. (2000). *Culture and pedagogy: International comparisons in primary education*. Blackwell.
ASIBEI. (2019). *Perfil de ingreso y egreso del ingeniero iberoamericano*. ASIBEI.

Barnard, S., Hassan, T., Bagilhole, B., & Dainty, A. (2012). 'They're not girly girls': An exploration of quantitative and qualitative data on engineering and gender in higher education. *European Journal of Engineering Education*, *37*(2), 193–204. https://doi.org/10.1080/03043797.2012.661702.

Bourn, D., & Neal, I. (2008). *The global engineer: Incorporating global skills within UK higher education of engineers*. Engineers Against Poverty/Development Education Research Centre, Institute of Education, University of London.

Bradley, C. (2014). Information use skills in the engineering programme accreditation criteria of four countries. *European Journal of Engineering Education*, *39*(1), 97–111. https://doi.org/10.1080/03043797.2013.833173

Cao, G. H. (2015). Comparison of China-US engineering ethics educations in Sino-Western philosophies of technology. *Science and Engineering Ethics*, *21*(6), 1609–1635. https://doi.org/10.1007/s11948-014-9611-3

Cao, Y., Ma, X., Case, J. M., Jesiek, B. K., Knight, D. B., Oakes, W. C., . . . Zhao, H. (2021). Visions of engineers for the future: A comparison of American and Chinese policy discourses on engineering education innovation. In *Proceedings of 2021 ASEE virtual annual conference*. ASEE.

Capretz, L. F., Waychal, P., & Jia, J. (2019). Comparing the popularity of testing careers among Canadian, Chinese, and Indian students. In *2019 IEEE/ACM 41st international conference on software engineering: Companion proceedings (ICSE-Companion)* (pp. 258–259). IEEE.

Carnoy, M. (2019). *Transforming comparative education: Fifty years of theory building at Stanford*. Stanford University Press.

Carr, M., Fidalgo, C., de Almeida, M. E. B., Branco, J. R., Santos, V., Murphy, E., & Fhloinn, E. N. (2015). Mathematics diagnostic testing in engineering: An international comparison between Ireland and Portugal. *European Journal of Engineering Education*, *40*(5), 546–556. https://doi.org/10.1080/03043797.2014.967182

Case, J. M. (2017). The historical evolution of engineering degrees: Competing stakeholders, contestation over ideas, and coherence across national borders. *European Journal of Engineering Education*, *42*(6), 974–986.

Case, J. M., Fraser, D. M., Kumar, A., & Itika, A. (2016). The significance of context for curriculum development in engineering education: A case study across three African countries. *European Journal of Engineering Education*, *41*(3), 279–292. https://doi.org/10.1080/03043797.2015.1056103

Cerda Suarez, L. M., & Hernandez, W. (2012). Leadership and performance in higher education: A comparative analysis in Portugal and Spain. *European Journal of Engineering Education*, *37*(6), 592–599.

Colomo-Palacios, R., Ben Yahia, N., & Larrucea, X. (2019). Gender diversity among computing students: Reflections from Norway, Spain and Tunisia. [Teem'19: Seventh international conference on technological ecosystems for enhancing multiculturality]. In *7th International conference on technological ecosystems for enhancing multiculturality (TEEM)*, Leon, SPAIN.

Committee on Prospering in the Global Economy of the 21st Century. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. National Academies Press.

Cui, J. (2013). Research on demands for higher engineering curriculum reform by society – based on the international comparison of the engineering professional organizations. *Higher Education of Sciences*, *4*, 64–70.

Du et al. (2019). An international comparative study on accreditation standards for engineering master's education. *Journal of World Education*, *476*, 48–52.

Duffy, G., Sorby, S., & Bowe, B. (2020). An investigation of the role of spatial ability in representing and solving word problems among engineering students. *Journal of Engineering Education*, *109*(3), 424–442. https://doi.org/10.1002/jee.20349.

Duque-Duque, D. A., & Rangel-Espejo, Y. C. (2021). *Estudio comparativo del programa de Ingeniería Industrial de la Universidad Católica de Colombia con Universidades a nivel Europa, Asia, América, Oceanía y África*. Universidad Católica de Colombia.

Fang, Z. (2014). A comparative study of accreditation of engineering education in signatories of Washington Accord. *Higher Education Development and Evaluation*, *4*(30), 66–76 + 119.

Feng et al. (2014). A study of key features of excellent engineering talents: An international comparative perspective. *Science and Technology in Chinese Higher Education*, *5*, 48–51.

Gardelle, L., Gil, E. C., Benguerna, M., Bolat, A., & Naran, B. (2017). The spread of European models of engineering education: The challenges faced in emerging countries. *European Journal of Engineering Education*, *42*(2), 203–218. https://doi.org/10.1080/03043797.2016.1241983.

Gong, X., Cardella, M. E., & Lei, Q. (2011). Comparative study of first-year engineering honors programs between US and China. In *ASEE annual conference and exposition*, Vancouver, Canada.

Granovskiy, B. (2018). *Science, technology, engineering, and mathematics (STEM) education: An overview*. Congressional Research Service.

Grenquist, S., & Hadgraft, R. G. (2013). Are Australian and American engineering education programs the same? The similarities and differences between Australian and American engineering accreditation procedures. In *ASEE international forum*, Atlanta, GA.

Guo, S., & Zhi, X. (2010). A comparative study of higher engineering education in China and the US. *Journal of Northwestern Polytechnical University (Social Sciences)*, *30*(1), 78–81.

Hamid Betancur, N. E., & Torres-Madronero, M. C. (2015). Accreditation of engineering programs in the region: A comparative analysis. *Revista Educación En Ingeniería*, *10*(19), 80–89.

Hanushek, E. A., & Woessmann, L. (2010). *The high cost of low educational performance: The long-run economic impact of improving PISA outcomes*. OECD Publishing.

Holmberg, M., & Bernhard, J. (2017). University teachers' perspectives on the role of the Laplace transform in engineering education. *European Journal of Engineering Education*, *42*(4), 413–428. https://doi.org/10.1080/03043797.2016.1190957.

Hu, D. (2020). Empowering the future: International comparison and standard reconstruction of engineering education professional accreditation system reform. *Journal of Tianjian University (Social Sciences)*, *22*(3), 223–229.

Karvar, A. (1995). Model reception in the domain of engineering education: Mediation and negotiation. *History and Technology, an International Journal*, *12*(2), 81–93.

Kember, D. (2016). Understanding and teaching the Chinese learner: Resolving the paradox of the Chinese learner. In R. B. King, & A. B. Bernardo (Eds.), *The psychology of Asian learners* (pp. 173–187). Springer.

Khattak, H., Ku, H., & Goh, S. (2012). Courses for teaching leadership capacity in professional engineering degrees in Australia and Europe. *European Journal of Engineering Education*, *37*(3), 279–296.

Kinnunen, P., Butler, M., Morgan, M., Nylen, A., Peters, A.-K., Sinclair, J., Kalvala, S., & Pesonen, E. (2018). Understanding initial undergraduate expectations and identity in computing studies. *European Journal of Engineering Education*, *43*(2), 201–218. https://doi.org/10.1080/03043797.2016.1146233.

Klassen, M., & Sá, C. (2020). Do global norms matter? The new logics of engineering accreditation in Canadian universities. *Higher Education*, *79*(1), 159–174.

Ku, H., Ahfock, T., & Yusaf, T. (2011). Remote access laboratories in Australia and Europe. *European Journal of Engineering Education*, *36*(3), 253–268. https://doi.org/10.1080/03043797.2011.578244.

Ku, H., & Goh, S. (2010). Final year engineering projects in Australia and Europe. *European Journal of Engineering Education*, *35*(2), 161–173.

Lahijanian, A., Devi, S. R., & Mukhapadhyny, B. (2010). Comparative attitude of civil engineering students towards environmental education in India and Iran. *Journal of Food Agriculture & Environment*, *8*(3–4), 1168–1173. <Go to ISI>://WOS:000286040100087.

Lau, K., Agogino, A. M., & Beckman, S. L. (2013). Global characterizations of learning styles among students and professionals. In *ASEE international forum*, Atlanta, GA.

Li, L., Yan, X., Yi, S., & Chen, B. (2013). Analysis and assessment of basic standard for graduates based on professional accreditation of engineering education: Learning from basic standard for graduates in Occident. *Journal of Architectural Education in Institutions of Higher Learning*, *22*(4), 27–33

Li, Y., Du, X., Xue, S., & Gao, X. (2013). Discussion on the internationalization idea for civil engineering by comparing the Sino-US civil engineering education. *China Science and Technology Information*, *5*, 116–117.

Litzinger, T. A., & Lattuca, L. R. (2014). Translating research to widespread practice in engineering education. In A. Johri & B. M. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 375–392). Cambridge University Press.

Liu, H. (2012). The reasons why higher engineering education in France, the United States, Germany and Russia is "excellence". *University Education Science*, *132*, 46–50.

Liu, Q., & Zhu, J. (2015). A comparison of standards for engineering master's in Europe. *Xue Wei Yu Yan Jiu Sheng Jiao Yu*, *10*, 71–77.

Loyalka, P., Carnoy, M., Froumin, I., Dossani, R., Tilak, J. B., & Yang, P. (2014). Factors affecting the quality of engineering education in the four largest emerging economies. *Higher Education*, *68*(6), 977–1004.

Lucena, J., Downey, G., Jesiek, B., & Elber, S. (2008). Competencies beyond countries: The re-organization of engineering education in the United States, Europe, and Latin America. *Journal of Engineering Education*, *97*(4), 433–447.

Lunev, A., Petrova, I., & Zaripova, V. (2013). Competency-based models of learning for engineers: A comparison. *European Journal of Engineering Education*, *38*(5), 543–555.

Luo, X., & Fan, C. (2018, February). Review of research on engineering ethics education in China and other parts of the world – a co-word analysis based on CNKI and WOS databases. *Forum of Chinese Science and Technology*, 169–179.

Ma, Y., Yang, X., & Zheng, X. (2010). International comparative study of graduate level engineering education accreditation. *Research in Higher Education of Engineering*, *4*, 60–63.

Manzon, M. (2011). *Comparative education: The construction of a field*. Comparative Education Research Centre, Springer.

Manzon, M. (2014). Comparing places. In M. Bray, B. Adamson, & M. Mason (Eds.), *Comparative education research: Approaches and methods* (pp. 97–137). Springer.

Noah, H. J., & Eckstein, M. A. (1969). towards *a science of comparative education*. The Macmillan Company.

Oda, S., Yamazaki, A. K., & Inoue, M. (2018). A comparative study on perceptions of cultural diversity in engineering students. In *10th International conference on education and new learning technologies (EDULEARN)*, Palma, SPAIN.

Palma, M., de los Rios, I., & Minan, E. (2011). Generic competences in engineering field: A comparative study between Latin America and European Union. In *3rd World conference on educational sciences (WCES)*, Bahcesehir Univ, Istanbul, Turkey.

Pedrosa, R. H. L., & Kloot, B. (2018). Engineering graduates in South Africa and Brazil: A common good perspective. In P. Ashwin & J. Case (Eds.), *Higher education pathways: South African undergraduate education and the public good* (pp. 274–287). African Minds.

Polmear, M., Bielefeldt, A. R., Knight, D., Canney, N., & Swan, C. (2019). Analysis of macroethics teaching practices and perceptions in engineering: A cultural comparison. *European Journal of Engineering Education*, *44*(6), 866–881.

Pu, Y., Yang, L., & Zou, J. (2010). A comparative study of engineering education accreditation in China and Japan. *Heilongjiang Education*, *3*, 39–42.

Reynolds, T. S., & Seely, B. E. (1993). Striving for balance: A hundred years of the American Society for Engineering Education. *Journal of Engineering Education*, *82*(3), 136–151.

Riley, D. (2017). Rigor/Us: Building boundaries and disciplining diversity with standards of merit. *Engineering Studies*, *9*(3), 249–265.

Riley, N. E. (2018). Good mothering in China: Effects of migration, low fertility, and birth constraints. In D. Poston Jr. (Ed.), *Low fertility regimes and demographic and societal change*. Springer. https://doi.org/10.1007/978-3-319-64061-7_7.

Santos, B., Virtudes, A., Goncalves, J., & Amin, S. (2018). Multicultural education in civil engineering: Planning and transportation approach. In *10th International conference on education and new learning technologies (EDULEARN)*, Palma, SPAIN.

Schmidt, W. H., Wang, H. C., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of Curriculum Studies*, *37*(5), 525–559.

Shen, X. (2013). A comparative study of engineering education reform in China and Germany. *Journal of Jilin Normal University (Humanities and Social Sciences)*, *41*(3), 109–111.

Song, S., Yang, S., Fu, G., Xu, K., & Niu, Y. (2012). Comparative study on safety engineering education and accreditation criteria between China and U.S. *China Safety Science Journal*, *22*(12), 23–28.

Tang, Y., & Lord, S. M. (2012). Comparison of practical training experiences for electronics engineers in China and the USA: Case study of Southeast University and the University of San Diego. In *2012 ASEE international forum* (pp. 17–19).

Tobin, J. J., Wu, D. Y., & Davidson, D. H. (1989). *Preschool in three cultures*. Yale University Press.

Turner, D. A. (2019). Comparative and international education: Development of a field and its method and theory. In C. C. Wolhuter & A. W. Wiseman (Eds.), *Comparative and international education: Survey of an infinite field* (pp. 11–28). Emerald Publishing Limited. https://doi.org/10.1108/S1479-367920190000036015.

Välimaa, J. (2008). On comparative research in higher education. In A. Amaral, I. Bleiklie, & C. Musselin (Eds.), *From governance to identity* (pp. 141–155). Springer. https://doi.org/10.1007/978-1-4020-8994-7_11.

Wang, H., Li, C., Zhao, S., & Li, X. (2020). A comparative study of educational certification and professional certification for registered engineers in civil engineering between China and the UK. *Journal of North China University of Water Resources and Electric Power (Social Science Edition)*, *36*(2), 46–52

Wang, J., Zhang, F., Xia, S., Wang, B., Zhang, J., & Tang, X. (2014). On the "substantial equivalence" of international accreditation and domestic accreditation for chemical engineering degree. *Research in Higher Education of Engineering*, *5*, 1–4.

Wang, Y. (2016). A comparison of general education for engineering students in China and US: Cases of Harbin Institute of Technology and University Wisconsin Madison. *Asia Pacific Education*, *10*, 116.

Wickenden, W. E. (1929). *A comparative study of engineering education in the United States and in Europe*. Lancaster Press.

Williams, B., Wankat, P. C., & Neto, P. (2018). Not so global: A bibliometric look at engineering education research. *European Journal of Engineering Education*, *43*(2), 190–200.

Wu, Z., & Xu, L. (2010). The research on the international comparison and the curriculum standards of solar energy engineering education. *Research in Higher Education of Engineering*, *6*, 77–81.

You, Y., Wang, Y., & Xie, H. (2017). A comparative study on western countries' engineering education professional certification standards. *Journal of Higher Education Research*, *40*(2), 73–79

Zartha Sossa, J. W., Orozco Mendoza, G. L., Arango Alzate, B., Vélez Salazar, F. M., Cortes, I., Agudelo, A., . . . Ríos Jaramillo, L. M. (2013). Análisis comparativo de programas de pregrado en ingeniería industrial en algunos países miembros de la oea. *Latin American & Caribbean Journal of Engineering Education*, 7(1).

Zhang, Y. (2016). A comparative study on the criterion system of program accreditation of higher engineering education between US and Japan. *Shanghai Journal of Educational Evaluation*, *1*, 52–55

Zhao, L., & Chang, T. (2020). Analysis on characteristics of engineering undergraduates' learning behavior in China and the USA. *Journal of Higher Education*, *41*(5), 97–109

Zhao, X., & Lin, J. (2011). An international comparative study on engineering talents training models. *Research in Higher Education of Engineering*, *2*, 33–41.

Zhu, J., & Cox, M. F. (2015). Epistemological development profiles of Chinese engineering doctoral students in US institutions: An application of Perry's theory. *Journal of Engineering Education*, *104*(3), 345–362.

Zhu, L., Lv, Z., & Li, W. (2015). The "computing" strategy of the great powers: Computing engineering and talent cultivation vision of Germany, the US and Russia. *Research in Higher Education of Engineering*, *4*, 10–12.

Zhuang, W., Zhang, P., Liu, H., & Wan, W. (2020). Mechanical engineering laboratory construction for accreditation: A comparison based on Chinese and Irish Mechanical Engineering Laboratories. *Jiaoyu Guancha*, *9*(29), 94–96, 100.