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Institutionalizing Engineering Education Research (EER) in China under the Context of New Engineering Education: Departments, Programs, and Research Agenda*

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Engineering Education Research (EER) in the Chinese context has been developed towards a region rather than a discipline with the intertwining of research and practice. The continuous development of dedicated research centers or departments, Ph.D. programs or tracks in China contribute to the increasingly diversified research agenda. By situating China's EER into the global landscape, this study contextualizes the unique mechanisms and characteristics of EER in China since the launch of the *New Engineering Education* initiative. Beginning with reviewing the diverse recognitions of EER and situating it in the global context, we gain insights from the current status of global EER. Bibliometric analysis is used to identify research agenda in order to outline the picture of EER in China. The results reveal that the growing recognition and hybrid structure of EER academic units with ill-defined graduate programs and tracks, and the attempts from diversified EER scholars share unanimous goals to innovate engineering education via all micro-, meso-, and macro-level research agenda. In this regard, we extend Klassen and Case's arguments about the nature of EER and argue that China's EER is a second-order region looking inward towards singulars represented by social sciences, and outward towards both engineering practice and educational policies. Meanwhile, it can be inferred that rather than unifying different claims to reach consensus in EER, the unanimous goals of EER shared by diversified groups of engineering education researchers help facilitating the institutionalizing process of EER in China. This work uncovers the institutionalizing process of China on academic infrastructures and research agenda to contribute to sharing China's EER experiences and status quo, for future potential engagement and dialogs in global EER.

Keywords: engineering education research (EER); China; New Engineering Education

1. Introduction

Engineering education research (EER) was sparse and limited before 2017; yet, calls for EER have burgeoned in China recently. Increasing efforts to improve quality and better educate future engineers have been led by the central government, for example, the *New Engineering Education* (*NEE*; Sometimes also referred to as *Emerging Engineering Education*, 3E [1]) initiative (i.e., *Outstanding Engineer Education 2.0* [2]) launched in 2017, and the *Initiative to Jointly Train Outstanding Engineers via University-Business Cooperation* (*UBC* Initiative [3]) launched in 2022. Meanwhile, 612 and 845 research and practical projects of the *NEE* were established successively to facilitate engineering education reforms that rooted in the overall higher education systems in China [4]. These two series of commissioned projects dramatically promoted engineering education reforms through synthesizing best practices across the nation, integrating efforts from stakeholders including engineering faculty, educational researchers, and industrial partners, and facilitating research from diverse epistemological perspectives with different methodologies in the fields of social science, particularly education [5]. At the same time, extracting research topics from national strategies and policies at macro level, the establishment of academic infrastructures such as EER centers have been simulating increasingly diversified projects at both meso and micro levels, for example, innovating teaching and learning practices at micro classroom level and re-structuring engineering education programs at meso institutional and departmental levels [6, 7]. However, consensus regarding its own paradigm of EER has not been reached yet between education academics and engineering faculty, which can be indicated by the different genres of knowledge structures, terminology, and methods used in in current EER-related studies.

With the rising awareness and recognition of the significant role of EER, it is imperative to analyze its recent trend and status quo to continuously innovate and improve the quality of engineering education in China. Even with the shared vision, the Chinese community of EER has not reach the consensus of the future research agenda in EER.

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Since becoming full signatory of the Washington Accord [8], the EER community in China has also been developing rapidly to contribute to international dialogs about both engineering education practice and research. As Borrego and Bernhard [9] indicated, understanding the varied settings and traditions of EER would contribute to increasing awareness and sensitivity, and bringing international perspectives. However, many Chinese engineering education researchers report their work in Mandarin rather than internationally, with limited access and communication with other scholars around the world. Therefore, this study aims to contribute to global dialog on EER in China in terms of departments, graduate programs, and research agenda in conceptualizing the overall landscape of EER. Also, we attempt to vocalize the distinct model of China's EER to enrich the body of knowledge in international engineering education. More specifically, our guiding research questions are:

RQ1: How is EER in China structured and conceptualized, in terms of departments, programs, and research agendas?
RQ2: What are the dominant legitimate claims in conceptualizing Chinese EER?

This paper is structured as follows. In the first part of our literature review, with attempt to better understand the distinct features of China's EER, we begin with situating it in global context from a comparative perspective [10] via reviewing current status and trajectory of EER globally, with emphasis on the U.S. and Europe [11–14]. This review intends to clarify the definition and recent development of EER. Then, we present our methods – bibliometric analysis – for selecting, screening, and analyzing journal articles related to China's EER. Afterwards, we address our main research question by analyzing articles and presenting the results to reveal the status quo of EER in China since the launch of the NEE in 2017. We then examine discussions building on and further extending the framework Klassen and Case [15] proposed in understanding arguments of EER. And finally, we conclude by arguing that China's EER is institutionalizing as a second-order region looking inward to social sciences and outward to both engineering practice as well as educational policies.

2. Literature Review

2.1 What defines EER

While EER has nearly one-century long but scattered history [16], diversified interests in EER to inform engineering education emerge to be "quiet no longer" since the 2000s [17]. Engineering education scholars engage in the discussion of the conceptualization and legitimacy of EER as a field [18, 19], community of practice (CoP) [20, 21], discipline [17, 22], and region [15]. The institutionalizing process of facilitating EER via Ph.D. programs and establishing academic departments or centers also provides solid evidence of EER as a discipline-based education research field [11, 23], attracting both engineering educators [19, 24] and social science researchers [25, 26]. As the editorial by Klassen et al. [27] indicated, EER might benefit from the value of broader literature and internationally comparative insights. The following paragraphs summarize the key descriptions of EER.

EER as a Community of Practice (CoP). Wenger and Snyder [28] outlined CoP by three interrelated dimensions: a *domain* of knowledge, with shared *practice* and a *community* of people. To this extent, EER emphasizes "practice" to reflect that EER absorbs an influx of knowledge and people from "intellectual neighbors" [29] such as engineering, education, social sciences, and other disciplines to inform engineering practice. In the United States, the National Science Foundation (NSF) funded *Rigorous Research in Engineering Education* workshops from 2004 to 2006 to promote EER development based on the idea of CoP [24, 30]. The efforts to build a CoP indicate the emergence of EER is a fundamentally social process with self-facilitated social structure and participants' common interests.

EER as a field or region. Jesiek et al. [11] indicated that the term *field* was a widely used and catch-all description for EER. For instance, Borrego and Bernhard [9] interpreted the emergence of EER as an internationally connected field of inquiry. EER embraced theoretical perspectives, frameworks, and methods from multiple disciplines [31], so as to facilitate understanding of student learning in engineering, identify theoretical supports for transforming engineering education, and evaluate the impacts of innovative reforms within the context of engineering education [32]. Taking the view that EER grew up in different disciplines and went towards engineering practice, Klassen and Case [15] further characterized EER as a second-order region based on Bernstein's field classification of singular or region. Their conceptual framework integrated Beddoes' work on arguments of rigor and methodological diversity claims of EER in U.S. [33], and Bernstein's classification of "singulars" and "regions" in fields of knowledge [34, 35]. According to Bernstein, fields could be categorized by singulars and regions from the perspective knowledge structure: singulars referred to established disciplines featured by developed theories and methods with clear boundaries [35], while regions drew on knowledge and built connections across different disciplines to inform "recontextualized" practice [36]. Therefore, second-order region implied that EER not only bridged engineering and education, but also relied on the parent singulars of education such as sociology, economics, psychology, and management to guide the practice of engineering education [15]. While lots of scholars argued to apply the term "singular" or "discipline", Klassen and Case advocated to use region to claim EER instead [15].

EER as a discipline or singular. Discipline usually implies a territory of academic knowledge and underlying disciplinary culture [37]. Discussions and calls from engineering education coalitions advance the disciplinary status of EER from scholarship of teaching and learning to disciplines with rigor [5, 17, 22, 38] and towards vigor when taking the critical lens [39]. In spite of this trend, the existing variations in framing EER as a discipline reveal the lack of consensus [11]. From a dynamic development perspective, EER can be perceived as a discipline based on Boyer's four-facet framework of scholarship (i.e., discovery, integration, application, teaching and learning) [40]. In another word, as a discipline, EER bridges the practice nature of engineering and reflective practice in education together, and draws on research traditions from social and behavioral sciences [5]. While growing as a discipline, well-defined research agenda on epistemologies, learning mechanisms, institutional environment, diversity and inclusiveness, and assessment are necessary for EER in U.S. context [41]. Borrego [42] and Jesiek et al. [11] indicated the development of EER as a discipline needed efforts to build shared consensus, agenda, goals, and objectives, which could borrow from the experience of science education research by establishing clear structural criteria (e.g., research journals), research criteria (e.g., scientific knowledge), and outcome criteria (i.e., implications for practice) [43]. To this extent, disciplinary "walls" and legitimacy are increasingly visible in EER [9].

2.2 EER in Globe

Disciplinary development in the United States and formation of CoP in Europe. EER is underway to be a global enterprise with increasing prominence [9, 44, 46]. Most early development of EER was based in the United States, featured by the support by NSF funds and the reinvention of *Journal of Engineering Education* (JEE) towards rigorous research [46]. Since the first decade of the 2000s, EER in the United State started the disciplinary development process of forming a new and accepted research paradigm [19], seeking to innovate and transform rather than reform engineering education [47], and address overarching and grand questions [17]. Alongside with the publication of The National Engineering Education Research Colloquies [41], disciplinary boundaries grew particularly strong in the United States [48]. EER gradually shifted from curriculum and instruction reformation to fundamental research on student learning in engineering [49, 50], with growing attention interests in using rigorous and diversified research methodologies to address broader research questions in EER [51], complimented with critical lens as well [39, 52].

Shortly afterwards, researchers from European counties actively joined the EER dialogs and facilitated it into an internationally connected field of inquiry [9] from multi-disciplinary perspectives and cultures [53]. Particularly, European scholars concerned more about scholarship regarding quality and academic contributions [32, 46], which was fundamental to the purpose and means by conducting EER. The bibliometric analyses of articles in two major journals and two major conference proceedings showed the tendency of global and collaborative EER in the Europe [46]. Scholars strived to address questions about student learning in engineering, find theoretical underpinnings to innovate engineering education, and evaluate innovation impacts [32]. The development of theoretical frameworks and perspectives and the advancement of methodology strengthened the consensus of EER in Europe "coming of age" as a CoP to cooperate and support researchers in engineering education as a looser network compared to the counterpart in the U.S [13]. The European kind of network tended to build on like-minded individuals interested in EER in order to facilitate dialogs and exchange ideas. For example, EER communities in Denmark, Finland and Sweden organized *Nordic Network in Engineering Education Research* and played a key role in offering the space for national networks, institutions and individuals to engage themselves in engineering education [12].

Academic infrastructures of EER worldwide. Besides advancing EER in terms of theoretical development and research methodologies, building academic infrastructure as structural criteria such as research journals, conferences, centers, and professional associations also enhanced the development of EER as a discipline. These growing EER-related efforts were particularly manifested through specialized journals, conferences and special interest groups within professional associations at the beginning, and academic departments or centers with graduate programs in a quick succession. Borrego & Bernhard analyzed and found the patterns of publishing in general education journals (e.g., *Higher Education*) or more domain-specific journals (e.g., *Chemical Engineering Education*) [9].

A majority of China's EER studies are published on *Research in Higher Education of Engineering* (RHEE), which was founded since 1983 and concentrated directly on EER. Ren & Yu compared five EER-related international journals and further indicated that China's EER fell behind in engaging in global community dialogs and focused more on macro-level policy analysis [26].

In addition to publication ventures, research capability got accelerated. Initially, JEE and EJEE spearheaded the *Advancing the Global Capacity for Engineering Education Research* project to promote global dialog and build networks within EER scholars and practitioners via a series of conference panels [44, 54]. Other international efforts included UNESCO's *International Center for Engineering Education*, and the *International Conference on Research in Engineering Education* (ICREE) [11, 19]. ICREE later reformatted into the *Research on Engineering Education Symposia* (REES) to work as a platform of sharing, discussing, disseminating, and propagating high-quality research and best practices within the global EER community, so as to share research interests and boost research capacity. REES is the signature event of the *Research in Engineering Education Network* consisted of members from the United States, Europe, Asia, Africa, Middle East and Russia. The European Union also established a thematic network on T*eaching and Research in Engineering in Europe* [55]. Professional associations and special interest groups also further promoted EER. These groups tended to sustain a research-based scholar community. For example, the ASEE Educational Research and Methods Division (ERM) aims to improve the quality of instruction in engineering education by disseminating knowledge on learning and teaching, encouraging efforts in innovative instructional design, and enhancing teaching in universities. The *European Society for Engineering Education* (SEFI) established the Special Interest Group on Engineering Education Research (SIG-EER) dedicated to gain knowledge and advance evidence-based educational reforms. *Australasian Association for Engineering Education* (AAEE) also launched varied Special Interest Groups with workshops and online resources.

Since EER has been recognizing as an emerging "discipline," academic units and graduate programs contribute to building legitimacy and recognition of EER. Centers and departments have been set at national or regional level such as the *Center for Engineering Education* of 4TU Federation, and at university level such as the *School of Engineering Education* at Purdue University. Most of such unit are located in the United States and Europe, some are based in Asian countries such as the *Center for Engineering Education* at KLE Technological University in India and the *Innovation Center for Engineering Education* at Pusan National University in South Korea. There also exist some institutions with emphasis on learning and teaching in engineering rather than directly on a more disciplinary agenda of engineering education. For instance, the *Center for the Integration of Research, Teaching, and Learning* in the United States aims at enhancing learning in STEM fields, and the *Center for Project-based Learning* at Worcester Polytechnic Institute serves as a hub for project-based learning via developing, curating and sharing best practices. Graduate programs include Ph.D. degree programs (e.g., EER Ph.D. at Purdue University [56, 57]), M.S. degree programs (e.g., EER M.S. at University of Michigan), and certificate programs (e.g., Graduate Certificate Program in Engineering Education at University of Florida). The establishment of EER departments and programs makes the newly developed discipline more visible worldwide, while inadequate focus but growing interests on EER also exist in other contexts beyond the United State and Europe.

3. Methodology

This article majorly utilizes bibliometric analysis with an analytical and visualized lens to investigate the conceptualization, structure, and legitimacy of EER in China with a focus on China's research agenda of EER. Bibliometric analysis uses large scale textual information, or publication metadata, associated with published articles to quantitatively evaluate the publications, scholars, journals, and authors' affiliations [26, 46, 58–61]. Using this method, previous EER scholars had attempted to explore the scholar collaboration patterns [59], citation networks [46] and the impact and coverage of topics [61] compliment to more traditional author and citation analysis, content analysis, and meta-analyses [10, 62, 63]. In this work, we followed the analysis and visualization workflow suggested by Börner et al. [64] and Heradio et al. [65], which composed four steps – data retrieval, data aggregation, preprocessing, and analysis, to reveal author distribution and keyword occurrence network that uncover to the formation and trends of research agenda of EER in China.

Our bibliometric analysis started from searching in the CNKI database and identifying published articles in RHEE during 2017–2022. We concentrated only on publications in RHEE, which serves directly to disseminate scholarly research in engineering education in China, and the majority of EER articles was written in Mandarin and published in this journal. In addition, the time period was selected purposefully to reveal recent trend of EER since the *NEE* initiative launched in 2017 [6, 7]. The literature search was operated on June 10, 2022 when there were only two issues published in 2022. Our searching process is revealed in Fig. 1 and structured as follows: (1) we searched the China National Knowledge Infrastructure (CNKI) database to include articles in RHEE from 2017 to 2022, and 1208 results were initially identified; (2) we screened the 1208 results and excluded non-journal articles such as "call for papers", then 1176 results remained; (3) we re-examined the 1176 articles firstly by abstracts and then by full articles to identify whether they are directly related to engineering education. As a result, 792 articles were remained finally and come into the data analysis process. From 2017 to 2022, 113, 115, 221, 135, 168, and 40 articles were finally included in our analysis respectively. We analyze all articles together rather than focusing on revealing the yearly trend as the holistic approach could better illustrate the recent trend after NEE initiatives and thus better serves answering our proposed research questions. Afterwards, CiteSpace was used for reformatting and transforming the publication metadata as well as identifying keyword clusters, and VOSviewer and Excel were applied to conduct bibliometric analysis for author collaboration network, keyword occurrence network, and associated visualization. We followed the recommended settings by CiteSpace and VOSviewer systems and other research which applied the similar analysis [10, 26, 46, 58–61, 63]. Using the same dataset, we also manually extracted and compiled information to answer our proposed research questions into four aspects of academic units, graduate programs, author affiliations, and research agenda of China's EER, shown in Fig. 1.

4. Findings

We analyze and organize our data in archived articles in RHEE compliment with relevant literatures, and structure our findings into four major aspects: (1) diversified ways of institutionalization of China's EER responding to the nation's developmental and societal needs with growing interests and recognition in EER; (2) EER graduate programs which deeply influenced by the education discipline need to be developed; (3) scholars with diversified backgrounds engage and contribute to EER; (4) research conducted at multiple (micro-, meso-, and macro-) levels complement to inform and shape Chinese research agenda.

4.1 Growing Recognition and Hybrid Structure of EER Academic Units

The establishment of academic units concentrated on engineering education emerged recently, with

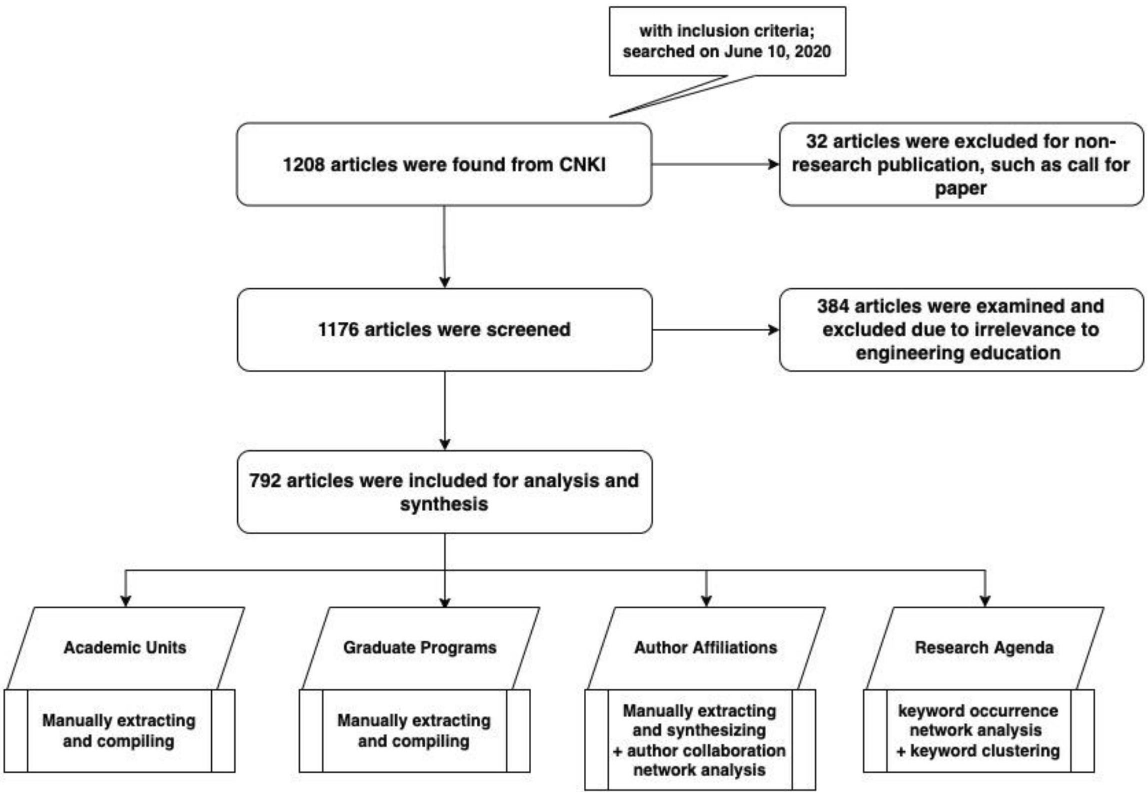

Fig. 1. Literature Search, Selection, and Analysis Process.

scattered purposes and research interests. Table 1 lists the founded academic units in China, which are collected from the institutions' official websites and reveals that the most common pathway for institutionalizing EER in China is embedding into a well-established educational department. The inclusion of EER as a separate unit within existing departments of education provides normalization legitimacy of recognizing EER as a sub-discipline of education. This kind of setting implies that EER rooting in educational research as a singular but also recognizing the unique needs of EER to inform engineering education practices with multiple perspectives.

Although most academic units of EER in China take root in institutes of (higher) education, there are also some variations of structure of EER departments. For instance, the *Center for Emerging Engineering Education* at TJU operates directly under the Office of Academic Affairs, and the *Center for Mechanical Engineering Research and Education at MIT and SUSTech* (a joint institution operated in China) is situated within an engineering department. The increasingly diversified structures of EER not only embed within universities as higher education academic units but also operate with other entities, for example, the *Engineering and Technology Education Research Center* operates in the government sector (e.g., Shanghai Education Commission). In addition, more than one EER-related academic units co-exist in some universities with multiple tasks and roles, such as research and advisory, as indicated in Table 1. The diversified modes of EER academic units indicate growing interests and visibility of the value of EER in China.

One unique feature for China's EER units is that they are frequently structured and designed to play an advisory role via conducting meso-level and macro-level research on reforms related to educational policies, rather than merely focusing on teaching and learning practice. For the advisory role, these academic units usually doing research with aims to provide suggestions for engineering education reform, meanwhile, their articles in RHEE tend to be policy-oriented, which pioneers and interacts with engineering education reforms at university, regional, and national levels. As a result, the legitimacy is inherited from educational research epistemologies and methods.

4.2 China's EER Graduate Programs and Tracks to be further developed

Regarding the formal and informal graduate programs or tracks shown in Table 2, EER is not a well-established discipline with consensus, demonstrated by varied structures and categories of EER graduate programs. Tsinghua University has been in the pioneering process of establishing Ph.D. program for engineering education as a sub-discipline embedded in the discipline of education. Other universities with traditions and strengths in engineering, such as TJU, are also attempting to normalize EER as an academic unit via disciplinary development, showing very recent initiatives to develop sub-disciplines in engineering education. While most EER-related programs operate as a track, a research field rather than a discipline concentrated on engineering education, located in a broader discipline of social sciences and exist as disciplinary concentrations of Higher Education or Educational Economics and Management. These programs and tracks are not directly intended to prepare graduate students for engineering instructors, but to research educational policies, among which some are related to engineering education. Moreover, curricular structures of the programs and tracks are designed similar to those of education without emphasizing on teaching methods in engineering context. Courses such as *Introduction of Engineering Education* and *Engineering Ethics* are commonest in curriculum. Therefore, EER in China should be still recognized as a field of inquiry with scattered interests rooted in education than a discipline conducting rigorous and full-scale research in engineering education [50], dominant by scholars from fields of social sciences represented by education. Regardless of whom educational researchers or engineering educators are conducting EER, legitimizing EER is a widespread and common concern [9], which requires supports from parent disciplines to eliminate the ambiguous identity of EER community. Yet the legitimation and specialization of EER might be jeopardized by aggravating scholarship in education and the separation between research and practice [66]. Because when there are only single source of education knowledge and governing rules between individual researchers and their institutions, a region with legal status will not be shaped [67]. Therefore, EER-related programs might also play a role in connecting engineering practices to educational research via bridging engineering faculty and education researchers with knowledge and expertise in both domains.

4.3 Attempts of Diversified EER Scholars to Engage in Engineering Education

Author affiliations reveal their educational and professional backgrounds, which implicitly answers who does EER. We reviewed the authors of the 792 RHEE articles and classified them into four groups: engineering educators (ENE), social science academics (SS, including education), administrative staff (ADMIN), and industrial staff (INDU). As

Table 1. EER-related Academic Units in China

	EER units (Founding year)	Affiliation	Institution(s)	Parent discipline dominant role(s)
1	Center for Research in Higher Engineering Education (2003)	Institute of Higher Education	Beihang University (BUAA) & Chinese Academy of Engineering (CAE)	Public Administration/ advisory and research
2	Engineering Education Research Center (2009)	Institute of Higher Education	East China University of Science and Technology (ECUST)	Educational Economics and Management/advisory and research
3	International Center for Engineering Education (ICEE) (2015)	Institute of Education	Tsinghua University (THU) & UNESCO	Higher Education/ advisory and research
4	Center for Engineering Education (2008)	Institute of Education	THU	None/advisory
5	Institute of Engineering Education (2020)	Institute of Education	THU	Higher Education/education and research in EER
6	Institute of Engineering Education (2019)	School of Education	Huazhong University of Science and Technology (HUST)	Higher Education/research
7	New Engineering Education Research Facility for Yangtze Economic Belt (2021)	School of Education & School of Continuing Education	HUST	None/research and engineering faculty development
8	Institute of Engineering Education (2010)	Institute of China's Science Technology and Education Policy (ISTEP)	Zhejiang University (ZJU)	Educational Economics and Management/research, education, and advisory
9	Center for Emerging Engineering Education (2018)	Office of Academic Affairs	Tianjin University (TJU)	Education/research
10	Engineering and Technology Education Research Center (2017)	None	Shanghai Education Commission	None/research
11	Center for Mechanical Engineering Research and Education at MIT and SUSTech (2018)	College of Engineering SUSTech & MIT Department of Mechanical Engineering	Southern University of Science and Technology (SUSTech) & MIT	Mechanical Engineering/ research and education in Mechanical Engineering
12	Research Center for Engineering Education	Higher Education Research Institute	Shantou University (STU)	Engineering/research
13	Capital Engineering Education Research and Development Facility (2011)	Faculty of Humanities and Social Sciences	Beijing University of Technology (BJUT)	Education/advisory
14	Engineering Education Research and Development Center (2019)	Directly under SUES	Shanghai University of Engineering Science (SUES)	None/research
15	Engineering Science and Education Strategy Research Center (2019)	Directly under CQU, jointly operating with the Institute Sustainable Development Center	Chongqing University (CQU)	None/advisory
16	Engineering Education Research Center (2018)	Higher Education R&D Center, Development Planning Center	Fujian University of Technology (FJUT)	None/research
17	Research Center for Technology and Engineering Education (2021)	Yangtze Delta Region Institute of Tsinghua University, Zhejiang	Tsinghua University & Zhejiang Provincial Government	None/research

Note. Data were collected and synthesized from institutions' official website and translated from Mandarin

summarized in Fig. 2, engineering educators, social science academics, and administrative staff account for primary contributors for EER in China. Based on the result, EER in China targets for dual goals to reform engineering education policy and integrate research and practice.

38.26% authors are engineering educators, 8.59% authors are teams of them with administrative staff, and 6.31% are cooperating with academics in social sciences. Some of the cooperation is deriving from their dual roles of engineering educators because they may also be in-job doctoral students in social sciences departments. The tendency of engineering educators participating in EER indicating their interests and passion in improving engineering education quality, which is closely related to practical goals, because engineering educators have deeper and better understandings about engineering practices, and possess strong pedagogical content knowledge situated in their specialty [9].

Table 2. EER-related Graduate Programs in China

	EER program(s)	Affiliation	University	Category
1	Ph.D. in Engineering Education	Institute of Engineering Education	THU	Second-order discipline under Higher Education
2	Ph.D. in Higher Education	School of Education	TJU	Higher Engineering Education and Higher Engineering Education Accreditation are tracks of Higher Education (Ph.D. in Engineering Education as second-order discipline is forthcoming)
3	Ph.D. in Educational Economics and Management	Institute of China's Science Technology and Education Policy (ISTEP)	ZJU	Engineering Education and Public Policy, Engineering Education as tracks
4	Ph.D. and M.S. in Higher Education	School of Education	HUST	Engineering Education as a track
5	Ph.D. in Educational Economics and Management	Institute of Higher Education	BUAA	Engineering Education as a track
6	M.S. in Educational Economics and Management	Institute of Higher Education	ECUST	Engineering Education as a track

Note. Data were collected and synthesized from institutions' official website and translated from Mandarin.

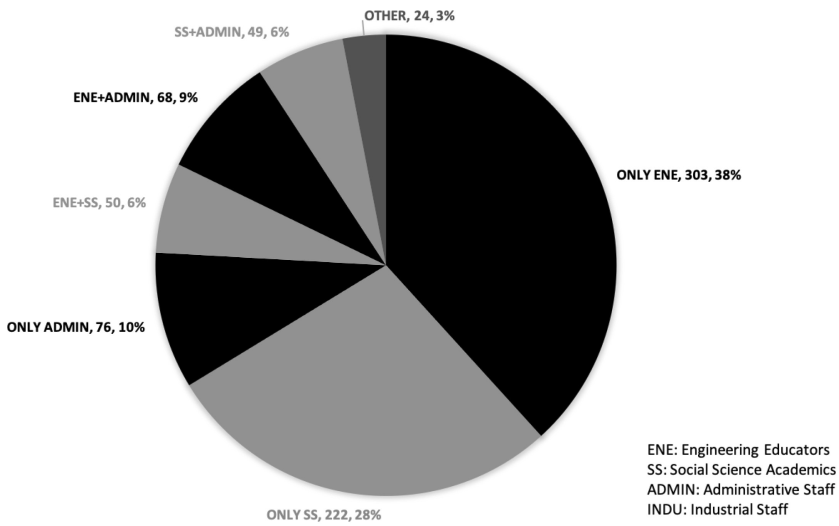

Fig. 2. Author Affiliation Groups of EER in RHEE (2017–2022).

However, they may also have conceptual difficulties and knowledge gaps to ground their research interests in engineering education into theoretical frameworks and research methods, to thoroughly and systematically reflect their practices and reforms [68]. These difficulties also imply the tension between practitioners and researchers on effectively improving engineering teaching and learning practices informed by educational research findings.

Regarding the 28.03% authors from academics in social sciences, particularly, educational researchers in EER, reforms of curriculums, pedagogies, and assessment are emphasized. However, they also face with crisis of fringe status in the broader area of educational research, as well as lack of recognition legitimacy from both engineering educators who questioning their understandings of being and doing engineering. The difference is that EER social science authors care more about institution-level issues and pedagogical theories, while engineering educators usually conduct classroom-level teaching and learning experiments and report their practical experiences. Thus, educational academics and engineering educators use different approaches and conduct research separately at meso and micro levels, but jointly lead engineering education reforms, such as innovating engineering course design, preparing students' knowledge and skills, transforming teacher-centered lectures to student-centered learning.

Another distinct feature of EER scholars is the involvement of administrative staff, 9.06% of the articles are published by this group alone. The attentions and insights from the provosts, deans, and staff from different sectors extend the scope and landscape of EER. They recontextualize and reconceptualize EER from more comprehensive and systematic perspectives at universities, or even the entire country levels to magnify the significance of EER in China, especially under the context of recent reforms such as *NEE* and *UBC* initiatives.

Significantly, although all groups of scholars are unanimous in improving engineering education, limited cooperative network among Chinese authors or their home institutions can be identified based on social network analysis. According to our author collaboration network analysis generated by CiteSpace and VOSviewer following the recommended setting, very weak correlation can be found - only distinct dyads, triads, or tetrads among the EER scholars can be identified. Similarly, there is very little cooperation within the EER scholars across institutions. Therefore, we choose not to represent this "network" in this study but interpret it as there exist little dialog and limited collaboration within the Chinese EER community, which deviates from the patterns found in U.S. or European based EER communities [59–61].

4.4 Research at All Levels to Inform and Shape Research Agenda

Keywords associated with published papers offer an important lens to identify research agenda of EER as keywords serve to summarize the major themes of past studies, which implied that EER is still ill-defined in China. Unlike EER in the United States centering on how students learn engineering [46], which clearly identifies the five major research areas including epistemologies, learning mechanisms, learning systems, diversity and inclusiveness, and assessment [41]; as well as EER in the Europe scopes and prioritizes practical goals of teaching and learning [9, 13]. Table 3 summarizes the most focused EER keywords (frequency >10), and Fig. 3 shows the keyword occurrence network. Top 6 keywords (frequency >20) include *New Engineering, engineering education, student training, industry-education synergy/university-business-collaboration (UBC), teaching and learning reform*, and *curriculum design*, which highlights the significance of engineering education reform driven by national policies. To distinguish the keyword directly translated from Mandarin, *New Engineering* here refers to the initiative launched by Chinese MOE in 2017 systematically reform engineering education; it is called *NEE* (*New Engineering Education* [1, 6, 7]) throughout this paper wherever else. Therefore, EER is facilitated not only to inform engineering practices but also to support national policies and initiatives, which is essential to bridge engineering practice and research with societal needs. In an influential paper, Lin indicated that *NEE* is exactly the action taken for engineering education to respond to the New Industry Revolution in terms of upgrading, integrating, and emerging engineering programs [69]. Specifically, how to train students towards the rapid development of industry and economics is the central question to China's EER. Correspondingly, the topics coupling with most occurred keywords include *reforming curriculum, instruction*, and *UBC*, indicating the efforts to prepare engineering students for the future profession, identify best engineering practices, and improve quality and adaptation of engineering.

Table 4 presents keyword clusters created by CiteSpace [70]. There are 269 clusters generated (N = 269) and indicating clear boundaries with a relatively high modularity score (Q = 0.67) and loose coupling with a low-density score (D = 0.01). However, the keywords within each cluster are highly similar as the mean Silhouette score is high (S = 0.92). *Experimental and practical instruction, interdisciplinary, engineering education, flipped-classroom*, and *CDIO* are top 5 clusters highlighted the most significant themes. These clusters illustrate the focus at classroom-level engineering education reforms, including emphasizing hands-on practice, the integration of knowledge and skills from various disciplines, pedagogical reforms such as flipped-classroom, and the continuous implementation of CDIO. For instance, the outcome-based education with emphasis on learning effectiveness such as the competence of complex problem solving can be achieved through the CDIO approach [71].

From the results of keywords analysis, four most prioritized research agenda were identified that illustrate interests and efforts in EER at all micro-,

Table 3. Keyword Frequency of EER Publications in RHEE 2017–2022

Keyword	Frequency	Year
New Engineering	171	2017
Engineering education	91	2017
Student training	45	2017
Industry-Education synergy/UBC	35	2017
Teaching and learning reform	31	2019
Curriculum design	25	2017
Student training model	18	2017
Experimental teaching and learning	18	2017
Accreditation	17	2017
Innovation	16	2017
Artificial Intelligence	14	2017
Pedagogy	14	2017
Higher education	13	2017
OBE	12	2017
CDIO	11	2017
Program development	11	2017
Engineering ethics	11	2017
UBC	10	2017
Course design	10	2019
Ideological education of courses	10	2019

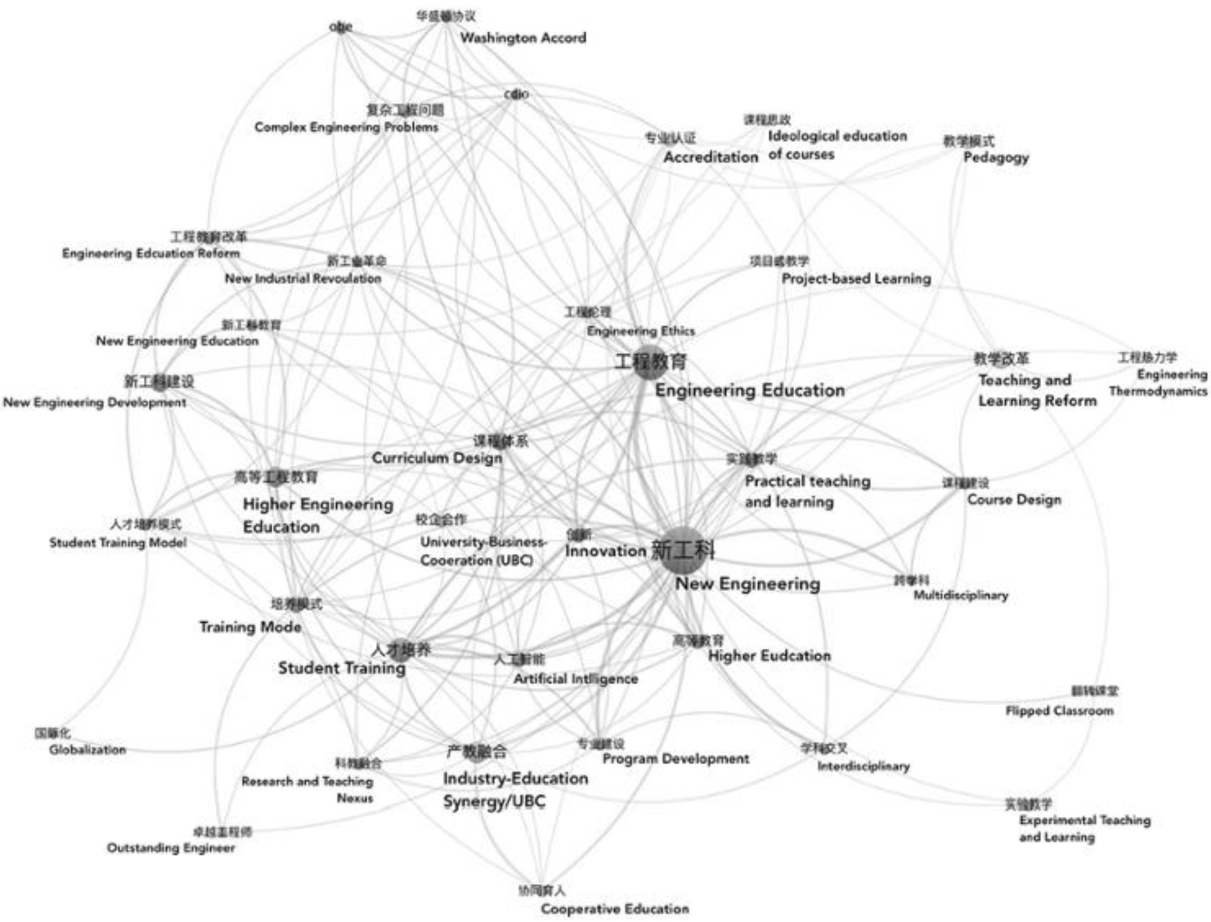

Fig. 3. Keyword Occurrence of EER Publications in RHEE 2017–2022.

Table 4. Keyword Clusters of EER Publications in RHEE 2017–2022.

Cluster	Size	Silhouette	Keywords with Top Frequency
Experimental and practical instruction	37	0.909	Experimental and practical instruction, student training, AI, innovation
Interdisciplinary	28	1	New Engineering, interdisciplinary, community, integration
Engineering education	26	0.894	Engineering education, engineering ethics, engineering, engineer, UBC
Flipped classroom	22	0.988	flipped classroom, teaching and learning reform, structural design, pedagogical model
CDIO	22	0.887	OBE, CDIO, complex problem solving, learning effectiveness
Industry-Education Synergy/UBC	20	0.878	Industry-Education Synergy/UBC, Cooperative education, globalization, interdisciplinary, institutionalization
Curriculum design	18	0.874	Curriculum design, course design, educational goals, engineering, learning outcomes
Accreditation	18	0.911	Accreditation, continuous improvement, ideological education of courses, classroom teaching, outcome-based
Training model	12	0.878	Training model, individualization, School of Industry, innovation competency
Engineering programs	8	0.907	Engineering programs, program development, program upgrading, internship

Note. N = 269 (number of clusters), Q = 0.6706 (modularity), D = 0.0103 (density), S = 0.9177 (mean Silhouette).

meso-, and macro-levels under the Chinese context, including:

(1) *New Engineering Education:* research which focused on engineering education innovations and reforms and took perspectives from both policies at macro level and instruction at micro level, with aims to identify best practices in engineering education innovations. Engineering education and the development of society are intertwined and reciprocated, therefore, how to educate future engineers towards

the new economics and new industry is becoming increasingly challenging and sophisticated, which calls for research at all levels to better prepare students for future-facing challenges of the exponential growth of new knowledge and information, global competition and rising needs of society. Therefore, the New Engineering Education agenda is crucial to achieve consensus via synthesizing insights from diversified stakeholders including policy-makers, educational academics, engineering educators, as well as administrative staff to enhance both normative legitimacy and cognitive legitimacy of EER in China.

(2) *Industry-education synergy or UBC mechanisms*: research centered on the cooperation between university and business in terms of actors/agents, educational activities, outcomes, and supporting mechanisms, and circumstances helps develop the emerging schema to prepare qualified engineers towards the rapid iterative industries. Actors in *UBC* are represented by governmental, industrial, and academic sectors partner in student training model re-construct, joint curriculum design and delivery, pedagogical innovation, and re-defining student competencies in need such as practical skills and professional skills to apply theorical knowledge to real-world engineering problems. Supporting mechanisms involve economic and financial, human resource, regulatory, and other non-coercive mechanisms; circumstances refer to political, economic, social, technological, and other environmental factors that may influence *UBC* implementation. Since *UBC* is a highly complex but rewarding approach in educating engineers, it is a feature aspect of EER in China.

(3) *Innovation in Curriculum and pedagogies*: research tackles on how students learn engineering by applying educational theories, pedagogies, and methodologies with explicit connection to specific engineering knowledge. In general, curriculum indicate what students need to know and pedagogies determine how students learn. Therefore, researchers from the broader field of education find value in applying horizontal knowledge and methodologies of social sciences in engineering education, with practical goals to innovate curriculum and pedagogies and improve quality of engineering education. The group of educational academics considers how learners in engineering programs integrate knowledge from mathematics, sciences, as well as engineering sciences to solve technical problems in industries from pedagogical and practical perspectives. Meanwhile, the group of engineering educators pays more attention to course design and structure, and the adoption of project-based learning for improving students' core competencies. These two groups of academics have a shared vision of improving quality of engineering education, but the tension between such groups lies in the various tacit knowledge and backgrounds influenced by different disciplinary traditions. This explains why the publications by engineering educators tend not to include convincing evidence and terminology, and the educational academics tend to leave from engineering practices. As Streveler and Smith indicate: "*When true collaborations between engineering faculty and learning and social scientist are formed, research in engineering education can contribute to learning theory, not only be informed by it*. [50, pp. 104]"

(4) *Engineering education in the digital age*: research on EER in the digital age so as to actively respond to the New Industry Revolution and to continuously inform engineering education practice. Specifically, this agenda centers on the use of emerging technologies to transform teaching and learning. Regarding the significant trends of the permeation and integration of information technologies in engineering education, especially under the COVID-19 situation, researchers and educators in all fields, jointly facilitate education reforms. Practices such as flipped-classroom and global hybrid classroom are adopted in teaching and learning. Similarly, research on pedagogical innovations, effectiveness, student perceptions and outcomes also guide the practices. For instance, Fu and Liu reported the adoption and effectiveness of iFabLab to innovate practical instructions in engineering at SJTU [71]. Establishing emerging engineering programs, such as AI and Robotics, comprises another aspect of this agenda, because the knowledge structures, instructional methods, and desired outcomes of these programs are developed differently from those in traditional engineering programs. For example, Fan et al. [73] and Zhou et al. [74] reported Robotics Engineering program development from the perspectives of knowledge structure and curricula and pedagogical innovation respectively. The rapid development of these emerging engineering programs highlights the urgency and necessity of bridging engineering educators and educational academics to jointly design the new engineering programs to satisfy the needs of both learners and industries.

Borrego and Bernhard proposed the criteria of quality scholarship in engineering education covering research questions and topics, theory and prior works, data and methodologies as convincing evidence, findings report, and international and interdisciplinary concerns [9]. Therefore, the research agenda of EER in China are approaching towards high quality scholarship but still remain possibilities to improve and innovate, aligned with the fast and diverse-changing new engineering practices.

5. Discussion

5.1 EER in China as a Region Looking Both Inward and Outward

This study situates China's EER into the global landscape by offering a snapshot of departments/centers, graduate programs/tracks, and research agenda since the *NEE* initiative. These academic infrastructures and research agenda not only indicate that China's EER is grounded in the Chinese history, culture, and tradition, but also influence who are doing EER and why diversified groups are conducting EER. Based on the analysis, we try to extend the conceptual framework from Klassen and Case [15] by locating EER in the Chinese context to include the tension between region inward and region outward insights in Fig. 4. Their arguments of EER for strong classification represented by the U.S., the region outward to practice represented by the Europe, and the most common status for the region inward from singular disciplines such as sociology and learning science are based on the knowledge structure perspective. However, this framework might be inadequately to reflect the joint efforts from various stakeholders who shape and influence the development of EER, which are particularly significant in the Chinese context. Accordingly, combining perspectives of structure (hybrid structure of EER in China) and stakeholders (four groups of who does EER), we further refine the framework of China's EER as a second-order region to find balance between region inward and outward. In particular, the region outward informs not only engineering practice but also evidence-based educational policies.

Our analysis leads us to situate EER as a region inward to social sciences (particularly, education) and outward to not only engineering practices but also educational policies. The inward aspect is in accordance with Klassen and Case's arguments that EER draws on educational and learning theories, methodological approaches, and other epistemology in social sciences [15]. Engineering education in China is regarded as a sub-discipline within higher education. Therefore, China's EER is deeply rooted in the more established field of higher education research, similar to the strong higher education base for EER in Nordic countries [12]. The tendency towards legitimating EER via establishing formal and informal departments/centers and programs/tracks with a hybrid structure makes this region more visible with clearer boundary. The outward aspect is what distinguishes China's EER for connecting not only engineering educational practice but also stakeholders in industries and governmental sectors to inform policies related to engineering education, responding to the fundamental goal of China's EER to prepare and produce future engineers in needs. In this regard, EER in China cannot be purely counted as scholar research centering on engineering education practice, findings from research agenda can be translated and applied to support policy-making. This unique status of region outward is achieved through the participation of diverse groups related to EER, especially driven by the normative legitimacy generated by national strategies.

5.2 Unanimous Goals but Different Approaches to Institutionalize China's EER

Different claims underpin China's EER. Although some scholars in EER call for institutionalizing

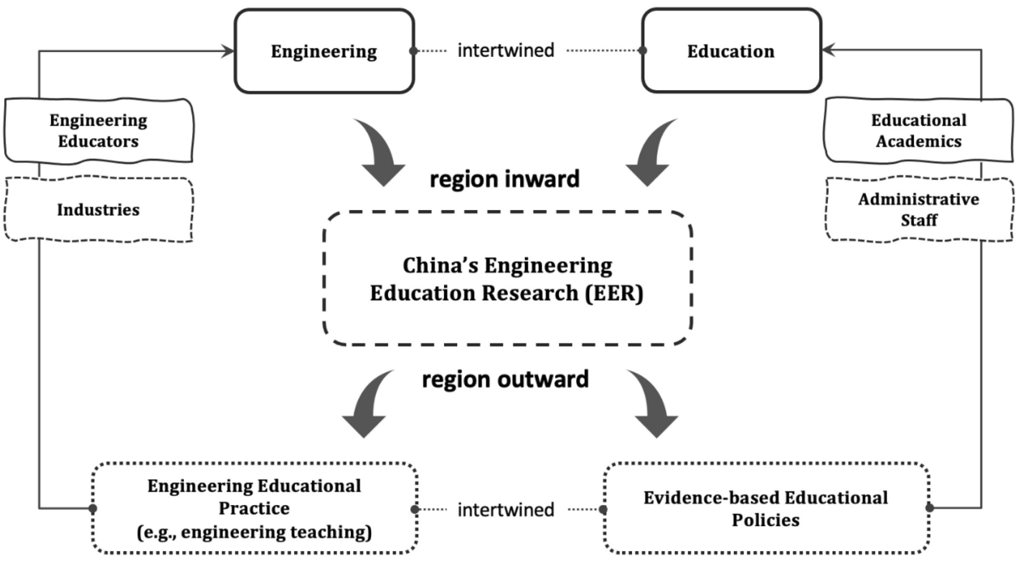

Fig. 4. Framework of China's EER as a second-order region, extended from Klassen and Case [15].

China's EER as a discipline [75], others still vocalize that disciplinary development and excessively scholarship of EER may bring the separation of research and practice [66]. Based on this study, we tend to argue that the institutionalization of China's EER is not "focused on a process towards discipline formation" [12, pp. 219], but a process driven by cognitive legitimacy to cultivate qualified engineers and innovate engineering education.

Although ill-defined standards underpin the institutionalization of EER in China, rather than unifying different claims to reach consensus, the unanimous goals of training qualified engineering education serve as the dominant cognitive mechanism of institutionalizing EER via the formation of a hybrid structure with diverse visions and academic infrastructures, which "wants to" engage in and contribute to the ongoing dialog about EER internationally. Also, the mimetic mechanism reacts as a complementary facilitator such that while EER in China is embedded in the region of higher education, EER has also begun to reverse this dominance by introducing different forms of EER institutions and involving stakeholders from different sectors. the growing identity and status of EER "ought to" be clarified. Normative forces from participants' existing disciplinary institutions continue to shape the research agendas, rather than directly ruling what EER "has to" institutionalize, particularly evidenced in formal graduate programs established as a second-order discipline of education in very recent years. In this case, China's EER develops by drawing legitimacy within the mature discipline of social sciences represented by education with well-defined epistemologies, and methodologies.

EER in China still focuses reform and practice with less consensus in theories, methodologies, and epistemologies. However, EER is not pure academic research among scholars [44], participation of the industry and administrative sectors is necessary to bridge research and practice via efficiently integrate strengths from different perspectives. The growing tendency to enhance the collaboration of different groups in the region of EER might help resolve the current limitation of only adapting the discipline-based research traditions. The way engineering faculty, administrative staff and the industry conducting EER is different from educational academics because of the less familiarity and training with terminologies and methodologies used in social sciences [50, 62], but they are proficient in practice within specific engineering domains with a traditional reform- and practice-oriented view [11]. What is also enlightening is that not only engineering practices should be emphasized and promoted by EER, but also lessons learned from EER have the potential to guide broader and more general reform in the higher education.

5.3 Limitations

We only introduce the most recent institutionalizing process of China's EER in this study, to investigate and recognize the its distinguished features relative to other countries or regions. This possible limitation also leaves us opportunities for future work to contribute in deeper understanding of EER in China by integrating historical and socio-cultural perspectives in current analysis. Also, we acknowledge that only publications in RHEE, China's flagship journal in EER, are included in our datasets. There also has been EER-related studies occasionally published in other journals written in Mandarin such as *China Higher Education Research* and *Journal of Higher Education Management* and written in English such as *International Journal of Engineering Education* and *IEEE transactions on Education*. Therefore, our analysis should be considered as exploratory and further work needs to go beyond RHEE to form a broader dataset to advance the knowledge of both academic infrastructures and research agendas. Dissertations concentrated on China's EER should also be considered.

6. Conclusion and Implication

This study reveals the landscape of EER in China from aspects of departments, programs, and research agenda under the context of the *NEE* initiative with an aim to contribute to global dialogs of EER. The institutionalization of EER in China is a process of integrating scattered interests into formal communities in terms of departments or centers with a hybrid structure and form, well-established graduate programs or tracks with tradition in the discipline of higher education, then to a region that combining research and practice with diversified research agenda. Building on our result, we further extend the conceptual framework to argue that EER in China is a region looking inward toward singular social sciences and outward toward both engineering practice and educational policies. Our analysis also implies the remaining room for China's EER to locate itself in the global context and actively join international dialogs to bring more voice and experiences of EER with internationally comparative focus to identify best practices. In addition, EER scholars might use find some insights from this article as a resource package to pinpoint the included part of information for further reference or collaboration. For non-Chinese engineering education researchers, this study identifies and acknowledges four major China's EER themes – national policy initiative, university-business collaboration, innovation in curriculum and pedagogies, and education in digital age – that they could expect to find some interesting views from China's experiences.

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References

1. Y. Cao, X. Ma, J. M. Case, B. K. Jesiek, D. B. Knight, W. C. Oakes, M. C. Paretti, X. Tang, Z. Xie and H. Zhao, Visions of engineers for the future: A comparison of American and Chinese policy discourses on engineering education innovation, *Proceedings of 2021 ASEE Annual Conference and Exposition*, Virtual, 2021. https://peer.asee.org/38030
2. Ministry of Education of the People's Republic of China, Opinions on Accelerating Implementation of the *New Engineering Education* Initiative and of *Outstanding Engineering Education 2.0*, 2018. http://www.moe.gov.cn/srcsite/A08/moe_742/s3860/201810/t20181017_351890.html. Accessed 13 June 2022.
3. Ministry of Education of the People's Republic of China, *University-Business Cooperating to Accelerate the Training of Outstanding Engineers in the New Era: The Initiative to Jointly Train Outstanding Engineers via University-Business Cooperation*, 2022. http://www.moe.gov.cn/jyb_xwfb/gzdt_gzdt/moe_1485/202203/t20220325_610710.html. Accessed 13 June 2022.
4. W. Yao, D. Mao, F. Li and S. Hu, Exploring the "Chinese Characteristics" in the construction of New Engineering-qualitative analysis of the "New Engineering Research and Practice" based on ground theory, *Research in Higher Education of Engineering*, **6**, pp. 173–180, 2021.
5. D. F. Radcliffe, Shaping the discipline of engineering education, *Journal of Engineering Education*, **95**(4), p. 263, 2006.
6. S. Wei, L. Zheng and M. Ohland, New Engineering Education initiative of China: A policy debrief, in *Proceedings of 2022 American Society of Engineering Education Annual Conference*, Minneapolis, MN, June 26–29, 2022.
7. T. Zhuang and X. Xu, 'New engineering education' in Chinese higher education: Prospects and challenges, *Tuning J. High. Educ.*, **6**(1), pp. 69–109, 2018.
8. Y. Wan and W. Chai, Chinese higher education will talk towards the world – Stories behind officially joining Washington Accord of Chinese engineering education, *Chinese Education Daily*, 2016. https://hudong.moe.gov.cn/jyb_xwfb/s5148/201606/t20160603_248175.html. Accessed 05 April 2021.
9. M. Borrego and J. Bernhard, The emergence of engineering education research as an internationally connected field of inquiry, *Journal of Engineering Education*, **100**(1), pp. 14–47, 2011.
10. B. K. Jesiek, M. Borrego, K. Beddoes, M. Hurtado and P. Rajendran, Mapping global trends in engineering education research, *International Journal of Engineering Education*, **27**(1), pp. 77–90, 2011.
11. B. K. Jesiek, L. K. Newswander and M. Borrego, Engineering education research: Discipline, community, or field? *Journal of Engineering Education*, **98**(1), pp. 39–52, 2009.
12. K. Edström, A. Kolmos, L. Malmi, J. Bernhard and P. Andersson, A bottom-up strategy for establishment of EER in three Nordic countries-the role of networks, *European Journal of Engineering Education*, **43**(2), pp. 219–234, 2018.
13. J. Bernhard, Engineering education research in Europe – Coming of age, *European Journal of Engineering Education*, **43**(2), pp. 167–170, 2018.
14. E. de Graaff, Ten years in engineering education research: Looking back ahead, *European Journal of Engineering Education*, **42**(6), pp. 587–590, 2017.
15. M. Klassen and J. M Case, Productive tensions? Analyzing the arguments made about the field of engineering education research, *Journal of Engineering Education*, **111**(1), pp. 214–231, 2022.
16. J. Strobel, D. Evangelou, R. A. Streveler and K. A. Smith, The many homes of engineering education research: Historical analysis of Ph.D. dissertations, *Proceedings of the Research on Engineering Education Symposium (REES)*. Davos, Switzerland, pp. 133–137, 2008.
17. K. Haghighi, Quiet no longer: Birth of a new discipline, *Journal of Engineering Education*, **94**(4), pp. 351–353, 2005.
18. F. Froyd and J. R. Lohmann, Chronological and ontological development of engineering education as a field of scientific inquiry. In *Cambridge handbook of engineering education research*, A. Johri and B. M. Olds, ed., Cambridge University Press, pp. 3–26, 2014.
19. M. Borrego, R. A. Streveler, R. L. Miller and K. A. Smith, A new paradigm for a new field: communicating representations of engineering education research, *Journal of Engineering Education*, **97**(2), pp. 147–162, 2008.
20. R. A. Streveler, K. A. Smith and R. L. Miller, Enhancing engineering education research capacity through building a community of practice, *Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition*. Portland OR, 2005.
21. R. Adams, C. Allendoerfer, P. Bell, H. Chen, L. Fleming, L. Leifer, B. Maring and D. Williams, A model for building and sustaining communities of engineering education research scholars, *Proceedings of the 2006 American Society for Engineering Education Annual Conference*, Chicago, IL, 2006.
22. P. C. Wankat, The emergence of engineering education as a scholarly discipline, *Proceedings of the 2004 American Society of Engineering Education Annual Conference*, Salt Lake City, UT, 2004.
23. L. C. Benson, K. Becker, M. M. Cooper, O. H. Griffin and K. A. Smith, Engineering education: Departments, degrees and directions, *International Journal of Engineering Education*, **26**(5), pp. 1042–1048, 2010.
24. R. A. Streveler and K. A. Smith, From the margins to the mainstream: The emerging landscape of engineering education research, *Journal of Engineering Education*, **99**(4), pp. 285–287, 2010.
25. A. Johri and B. M. Olds, Situated engineering learning: bridging engineering education research and the learning sciences, *Journal of Engineering Education*, **100**(1), pp. 151–185, 2011.
26. L. Ren and D. Yu, Research on the international status and influence of China's engineering education research, *Research in Higher Education of Engineering*, **6**, pp. 182–187, 2018.

27. M. Klassen, D. B. Knight, X. D. Tang, N. Wolmarans and J. M. Case, Using higher education and other social sciences research to inform engineering education research: A cross-national perspective, *Journal of Engineering Education*, Guest editorial, **111**(3), pp. 1–4, 2022.
28. E. C. Wenger and W. Snyder, Communities of practice: the organizational frontier, *Harvard Business Review*, **78**, pp. 139–145, 2000.
29. E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*, New York: Cambridge University Press, 1998.
30. M. Borrego, R. A. Streveler, N. Chism, K. A. Smith and R. Miller, Developing an engineering education research community of practice through a structured workshop curriculum, *Proceedings of the 2006 American Society for Engineering Education Annual Conference*, Chicago, IL, 2006.
31. L. H. Jamieson and J. R. Lohmann, *Creating a culture for scholarly and systematic innovation in engineering education: ensuring U.S. engineering has the right people with the right talent for a global society*, American Society for Engineering Education, Washington, DC, 2009.
32. L. Malmi, T. Adawi, R. Curmi, E. de Graaff, G. Duffy, C. Kautz, P. Kinnunen and B. Williams, How authors did it – a methodological analysis of recent engineering education research papers in the European Journal of Engineering Education, *European Journal of Engineering Education*, **43**(2), pp. 171–189, 2018.
33. K. Beddoes, Methodology discourses as boundary work in the construction of engineering education, *Social Studies of Science,* **44**(2), pp. 293–312, 2014.
34. B. Bernstein, 'Vertical and horizontal discourse: an essay', *British Journal of Sociology of Education*, **20**(2), pp. 157–173, 1999.
35. B. Bernstein, *Pedagogy, Symbolic Control, and Identity: Theory, Research, Critique*. Rowman & Littlefield, New York, 2000.
36. J. Hordern, Recontextualization and the education–work relation, In *Knowledge, Curriculum and Preparation for Work*, S. Allais & Y. Shalem, Ed., Brill Sense, pp. 68–88, 2018.
37. T. Becher and P. Trowler, *Academic Tribes and Territories*, New York: McGraw-Hill, 2001.
38. H. Guo, K. Zhu and C Yan, From "scholarship of teaching" to "educational research": a historical analysis of the formation of engineering education discipline in the United States, *Research in Higher Education of Engineering*, **6**, pp. 13–21, 2013.
39. D. Riley, Rigor/us: Building boundaries and disciplining diversity with standards of merit, *Engineering Studies*, **9**(3), pp. 249–265, 2017.
40. E. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate*, Jossey-Bass, San Francisco, 1990.
41. R. Adams, D. Aldridge, C. Atman, L. Barker, M. Besterfield-Sacre, S. Bjorklund and M. Young, The research agenda for the new discipline of engineering education, *Journal of Engineering Education*, **95**(4), pp. 259–261, 2006.
42. M. Borrego, Development of engineering education as a rigorous discipline: A study of the publication patterns of four coalitions, *Journal of Engineering Education*, **96**(1), pp. 5–18, 2007.
43. P. Fensham, *Defining an Identity: The Evolution of Science Education as a Field of Research*, **20**, Springer Science & Business Media, Dordrecht, 2004.
44. B. K. Jesiek, M. Borrego and K. Beddoes, Advancing Global Capacity for Engineering Education Research (AGCEER): Relating research to practice, policy, and industry, *European Journal of Engineering Education*, **99**(2), pp. 107–119, 2010.
45. B. Williams, P. C. Wankat and P. Neto, Not so global: a bibliometric look at engineering education research, *European Journal of Engineering Education*, **43**(2), pp. 190–200, 2018.
46. J. R. Lohmann, Building a community of scholars: the role of the journal of engineering education as a research journal, *Journal of Engineering Education*, **94**(1), pp. 1–6, 2005.
47. G. Gabriele, Advancing engineering education in a flattened world, *Journal of Engineering Education*, **94**(3), pp. 285–286, 2005.
48. A. Abbott, *Chaos of disciplines*, Chicago: The University of Chicago Press, 2001.
49. S. Fincher and R. Adams, Interactive session-developing engineering education research questions: what do they look like? How do I get one? *Proceedings of 2004 ASEE/IEEE Frontiers in Education Conference*, Salt Lake City, Utah, 2004.
50. R. A. Streveler and K. A. Smith, Conducting rigorous research in engineering education, *Journal of Engineering Education*, **95**(2), pp. 103–105, 2006.
51. J. M. Case and G. Light, Emerging methodologies in engineering education research, *Journal of Engineering Education*, **100**(1), pp. 186–210, 2011.
52. A. Pawley, Learning from small numbers: Studying ruling relations that gender and race the structure of U.S. engineering education, *Journal of Engineering Education*, **108**(3), pp. 13–31, 2019.
53. J. Bernhard and C. Baillie, Standards for quality of research in engineering education, *International Journal of Engineering Education*, **32**(6), pp. 2378–2394, 2016.
54. J. R. Lohmann and E. De Graaff, Advancing the global capacity for engineering education research: A year of international dialogue, *2008 ASEE Annual Conference & Exposition*, Pittsburgh, 2008.
55. C. Borri and F. Maffioli, *TREE: Teaching and research in engineering in Europe: Re-engineering engineering education in Europe*, Firenze University Press, Firenze, Italy, p.7, 2007.
56. L. Zheng and S. Wei, The competency framework and pathways for educating doctoral students in engineering education-take Purdue University as an example, *Research in Higher Education of Engineering*, **3**, pp. 190–196, 2021.
57. M. Li, Q. Yang and Y. Shen, A study on the PhD program in engineering education in the U.S. – taking Purdue University as an example, *Research in Higher Education of Engineering*, **5**, pp. 194-200, 2019.
58. C. Borgman and J. Furner, Scholarly communication and bibliometrics, *Annual Review of Information Science and Technology*, **36**, pp. 3–72, 2002.
59. H. Xian and K. Madhavan, Anatomy of scholarly collaboration in engineering education: A big-data bibliometric analysis, *Journal of Engineering Education*, **103**(3), pp. 486–514, 2014.
60. S. Han, J. Xie and X. Xiao, Bibliometric analysis of international higher engineering education research, *Research in Higher Education of Engineering*, **6**, pp. 148–155, 2020.
61. C. Brozina, A. Katz and A. Johri, Taking stock: Analysis of IJEE publications from 1996–2020 to examine impact and coverage of topics, *International Journal of Engineering Education*, **37**(5), pp. 1146–1160, 2021.
62. M. Koro-Ljungberg and E. P. Douglas, State of qualitative research in engineering education: Meta-analysis of JEE articles, 2005–2006, *Journal of Engineering Education*, **97**(2), pp. 163–175, 2008.

63. S. Nawaz and J. Strobel, Authorship and content analysis of engineering education research: A case study, *International Journal of Engineering Pedagogy*, **6**(2), pp. 39–51, 2016.
64. K. Börner, C. Chen and K. W. Boyack, Visualizing knowledge domains, *Annual Review of Information Science and Technology*, **37**(1), pp. 179–255, 2003.
65. R. Heradio, L. De La Torre, D. Galan, F. J. Cabrerizo, E. Herrera-Viedma and S. Dormido, Virtual and remote labs in education: A bibliometric analysis, *Computers & Education*, **98**, pp. 14–38, 2016.
66. P. Wang, Engineering education research in China: decline and revival, *Research in Higher Education of Engineering*, **6**, pp. 13–21, 2013.
67. B. Coriat, F. Orsi and O. Weinstein, Does biotech reflect a new science-based innovation regime? *Industry and Innovation*, **10**(3), pp. 231–253, 2003.
68. M. Borrego, Conceptual difficulties experienced by trained engineers learning educational research methods, *Journal of Engineering Education*, **96**(2), pp. 91–102, 2007.
69. J. Lin, The New Engineering education towards future in China, *Tsinghua Journal of Education*, **38**(2), pp. 26–35, 2017.
70. C. Chen, CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature, *Journal of the American Society for Information Science and Technology*, **57**(3), pp. 359–377, 2006.
71. M. Ye, H. Kong and X. Xu, Exploration into the practical paths of emerging engineering education: construction of CDIO transformation platform based on grounded theory, *Research in Higher Education of Engineering*, **4**, pp. 11–17+100, 2018.
72. Y. Fu and T. Liu, iFabLab: A novel action-learning model based on emerging engineering education, *Research in Higher Education of Engineering*, **5**, pp. 30–36, 2020.
73. L. Fan, K. Jiang, H. Zhu and C. Zhang, On robot knowledge system and course content under New Engineering background, *Research in Higher Education of Engineering*, **2**, pp. 32–38, 2021.
74. M. Zhou, Z. Cao and Q. Wu, On the teaching reform of robotic technology based on "Five-in-One" strategy, *Research in Higher Education of Engineering*, **4**, pp. 66–70, 2020.
75. D. Yu, D. Yuan and J. Yuan, How China's engineering education research moves to institutional development-based on the perspective of international comparison, *Research in Higher Education of Engineering*, **3**, pp. 17–23, 2021.

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