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RESEARCH ARTICLE

A review of university-enterprise-cooperation research in China: a quantitative perspective

Shang Zhang^{1*}, Hongxia Duan², Tingting Wei³, and Galvin Shane⁴

¹Department of Construction Management, Suzhou University of Science and Technology, Jiangsu Province, China. Corresponding author: zhangshfan@163.com.

²School of Civil Engineering, Suzhou University of Science and Technology, Jiangsu Province, China. Email: dhx123@mail.usts.edu.cn.

³Department of M&E and Construction Engineering, Nanhu College of Jiaxing University, Zhejiang Province, China. Email:157427533@qq.com.

⁴School of Engineering, University of South Wales, Pontypridd, Wales, UK. shane.galvin@southwales.ac.uk.

***Corresponding author:** Shang Zhang, Department of Construction Management, Suzhou University of Science and Technology, Jiangsu Province, China. Email: zhangshfan@163.com.

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Abstract

The University-Enterprise-Cooperation (UEC) has been adopted by many universities globally to effectively utilize the high-quality resources of the construction industry, to improve the general competence, problem-solving skills and innovation capability of graduates of an engineering discipline. There are a limited amount of papers published in international journals on UEC, compared to a significant volume of Chinese published literature. However, based on the best knowledge of the authors, no existing literature has conducted a quantitative statistical analysis on UEC research in Chinese and international journals. In order to fill this knowledge gap, 300 high-quality papers on UEC were derived through the Chinese CNKI database from 2010-2019. The general development trend of UEC research in the past 30 years was also mapped and analyzed. The most popular topics under the UEC theme and the most frequently adopted research methods within the UEC field were also identified. It was found that since the first UEC publication in 1990, the number of UEC publications experienced a steady increase during the last decade, aided by strong promotion from the government and active practice within universities and from educators in China. Course development (52.94%) and practice resource development (24.89%)

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were two of the most popular research topics in the UEC field. The elaboration research method was adopted by more than half (55.94%) of UEC papers, followed by case study (21.25%). The findings of this study are valuable for researchers and practitioners globally, to better understand the development status of UEC research in China and embark on future research in this field.

Keywords:

University-enterprise-cooperation (UEC), course development, practice resource development, research topic, research method.

Introduction

The University-Enterprise-Cooperation (UEC), also interpreted as Industry-University Partnerships (Tener, 1996; Smith, et al. 2018) and Academia-Industry Cooperation (Shapira and Rosenfeld, 2011), refers to a pedagogical form of education approach and thinking, which focuses on the cultivation of graduates with a high-level of innovation capability and practical skills, through the full utilization of resources from both the university and company/industry (Liu and Zhong, 2011). As claimed by Russell and Stouffer (2003), a large number of undergraduate programs for generating construction professionals were not specifically articulated to enable the students to become effective and skilled project managers. Hence, the university, the construction industry, professional organizations, and the government should form a broad collaboration to develop competent construction professionals with strong leadership skills (Toor and Ofori, 2008). American Society of Civil Engineers (ASCE) also recognized this problem and designed the practitioner-in-residence program for students studying on civil engineering programs. It was recommended that engineering faculties should try to develop their own practical skills, which might be achieved through working in the construction industry and networking with practicing engineers (Koehn, 2004). Furthermore, the National Academy of Engineering (NAE) published a report in 2005, with the title of *Educating the Engineer of 2020*, which emphasized the importance of collaboration between industry and academia to produce engineers with strong theoretical backgrounds and practical experiences (NAE, 2005). Gann (2001) argued that academic researchers generally published in refereed journals, whereas for applied research in construction-related areas it was not the most appropriate form of producing research output, either for improving knowledge or for disseminating it to the construction industry. Research by Shapira and Rosenfeld (2011) also indicated that cooperation between academia and the construction industry was critical in achieving success of an innovative research and development (R&D) project, and without this cooperation the R&D effort could not be achieved.

In recent years, the Chinese government through different levels, has attached great importance to UEC in higher education. For example, the Ministry of Education has emphasized many times in their guidance documents, specifying that high attention should be paid to UEC with the aim to improve the practical working capability of the graduates. Universities should strengthen close collaboration with the industry and provide more practical training and internship opportunities to the students, through the joint effort of universities and industry (Xiao and Fan, 2017).

Construction management is a practice-oriented discipline (Zhang, Galvin and Duan, 2018). More than 440 universities or colleges offer construction management undergraduate programs in China. With the economic structure adjusting and the acceleration of

construction industry development, construction management graduates from some Chinese universities or colleges are struggling to find appropriate jobs or secure jobs with promising career opportunities. On the contrary, many construction companies and real estate developers complain that it is difficult to find suitable graduates with high competency levels in terms of industry development awareness, strong problem analyzing and solving capabilities, communication skills, and the ability to integrate into a teamwork environment. Hence, a contradiction between the talent supply (universities) and demand (construction companies) does exist in China, which needs a paradigm shift in terms of the educational approach and thinking, to significantly improve the general quality of construction management graduates, to better meet the requirements of a modern and evolving construction sector.

In order to fully illustrate the background of UEC, it is also necessary to elaborate the paradigm shift of undergraduate education across the world during the last 30 years, which is from a “teaching paradigm” to a “learning paradigm”, or a “lecturer-centred paradigm” to a “student-centred paradigm”. Under the new paradigm (“student-centred paradigm”), the purpose of education within universities is not limited to teaching, but also to providing an excellent learning environment which fosters the students’ self-learning or learning in a most effective way (Lin, 2017). In the new learning paradigm, new learning approaches emerged and were widely adopted by an increasing number of lecturers in the universities. These learning approaches include Problem-based Learning, Case-based Learning, Project-based Learning and Experimental Learning (Lin, 2013a). However, most of the lecturers in engineering universities and colleges lack experience in engineering practice, and they have limited capability to solve real-world engineering problems, which makes it difficult for them to effectively adopt these new learning approaches. Most of the time, problems and cases are not collected and derived from real-world engineering practice or company operations, which means they are hypothesized by the lecturers. In this case, it has a negative impact on the cultivation and improvement of students’ general competence in the engineering discipline. Through collaboration between universities and industry, high-quality resources within companies, such as real-world construction problems and lessons learned in successful or failed projects, can be directly used in the lecture delivery process. This will facilitate the new learning approaches being effectively adopted in the university course delivery process. Hence, from the perspective of a new learning paradigm shift in recent years, it is also necessary to bridge the university teaching and industry practice in the construction management field.

In fact, universities and colleges globally have a long history of adopting different ways of cooperation with companies in the cultivation of engineering graduates to make up for their weakness in practical education and vocational training. Specifically, there are the German BBS (Berufsbildenden Schule) model, the UK Sandwich model, and the Australia TAFE (Technical and Further Education) model. In terms of the BBS model, the capability requirements and standards of the graduates are jointly defined by the universities and companies. The universities or colleges are responsible for teaching professional knowledge of a specific discipline, and the companies are mainly responsible for the training of students’ practical working skills. As a result, the discipline theory and practice form an integral part, which is effective to improve the general competence of graduates. As to the “Sandwich” model in UK, the overall learning process is divided into three stages. In the first stage, the students learn basic theory in universities or colleges, followed by the next stage during which they work in a company to learn practical knowledge and develop practical working skills. Then in the third stage, they return to the universities or colleges to complete their studies and

obtain a graduation certificate. In Australia's TAFE model, the universities or colleges work closely with the industry. The TAFE universities or colleges generally have a board of directors. In some cases, the chairperson of the board of directors and the majority of board members are industry experts. The companies participate in evaluating the overall learning process of the graduates. Most of the universities or colleges establish a strong practice or internship base with the industrial partners (Lin, 2012). In all the three models (i.e. BBS, Sandwich and TAFE), a comprehensive and close cooperation between the universities or colleges and companies or industry is the common thread to improving the competence of their graduates.

In recent years, the practical adoption of UEC has been highlighted by educators and government departments in China, and as a result research on this topic has also been gradually increasing. However, currently literature which explores the research progress and trend of UEC in China and across the world is limited. This paper utilizes the China National Knowledge Infrastructure (CNKI) database, one of the largest and most popular academic databases in China as the literature source, and adopts a quantitative analysis method to answer the following three questions:

- (1) What is the development status of UEC research in Chinese journals in chronological order?
- (2) What topics emerge from UEC research in Chinese journals in the ten-year period from 2010–2019?
- (3) Which research methods are frequently adopted by UEC researchers in the ten-year period from 2010–2019?

In order to answer the above three questions, 300 papers (30 papers each year) published in Chinese journals with UEC theme were derived and reviewed by the authors. The research topic and research method of each paper were also identified through content analysis method, followed by statistical analysis of the result. In addition, the UEC development history and benefits of applying UEC in practice were also critically reviewed in the engineering discipline with the educational experience across the world. The findings of this study are valuable for researchers and practitioners worldwide to better understand the development and trend of UEC research in China. This study is also helpful for universities or colleges offering construction management program to find a suitable cooperation approach between the universities and companies, with reference to the general UEC models in Chinese and international institutions.

This paper is organized as follows: In Section 1, the research background is introduced. In Section 2, the development of and research on UEC is reviewed. In Section 3, the research method of this study, specifically the data collection process from the UEC papers in Chinese journals and data analysis methods is presented. In Section 4, the chronology of UEC publications in Chinese journals is illustrated. In Section 5, the research topics of the selected 300 UEC papers in Chinese journals are identified and statistically analyzed, and the change of the topics over the last decade are illustrated. In Section 6, the research methods adopted by UEC researchers in the selected 300 UEC papers are identified and analyzed. In Section 7, main conclusions as well as limitations and future research directions are presented.

Literature review

Industry-University Partnerships were first applied through co-op programs in engineering programs in the USA in 1906 and in Canada in 1957 (Haddara and

Skanes, 2007). The Construction Engineering and Management (CEM) program at the Purdue University was established in 1972, and as a requirement for obtaining the BSCEM degree, each student had to satisfactorily complete three 12-week internships at a construction company (Tener, 1996). The most notable example of UEC is the Construction Industry Institute (CII) which is based on the University of Texas-Austin (Back, 2008). Established in 1983, the CII is a consortium of employer, engineering companies and construction companies that engage collaboratively with academics at the university, in creating, disseminating and practicing knowledge. Hence, CII's role in promoting innovation through the collaboration between the construction industry and university academia is paramount (Shapira and Rosenfeld, 2011). Another example is the Learning Factory at Penn State University, which was established in 1994 and in 2006 it won the National Academy of Engineering Bernard M. Gordon Prize for Innovation in Engineering and Technology Education (Lamancusa, et al. 2008). The success of the Learning Factory was attributed to the active participation of construction professionals from the construction industry (Smith, et al. 2018). In 2001, the Architectural Engineering Department at the University of Nebraska-Lincoln, with the partnership of industry, started an industry-experienced graduate student program. All parties to the first offering were satisfied with the outcomes and believed that the benefits significantly outweighed the costs incurred (Waters, Alvine and Eble-Hankins, 2011). In Hong Kong, a multimedia educational package, called as CIVCAL, was utilized to support teaching and learning in civil engineering as well as building and construction undergraduate programmes. The online multimedia portal facilitated virtual site visits to the completed and ongoing construction projects in Hong Kong, through photographic and videographic applications. The online facility proved to be a significant success in consolidating a more practical teaching and learning environment in construction-related disciplines of those universities in Hong Kong (Toor and Ofori, 2008). In China, Shanghai Jiaotong University established an integral teaching-learning centre with Shanghai Baosteel Group, to jointly offer postgraduate (Master and PhD) degrees, which was considered as a successful pedagogical strategy to sustain the development of innovative capabilities of university graduates (Wu and Du, 2008).

Dulaimi, et al. (2002) argued that the lack of cooperation between academia and industry is a primary hindrance to innovation in the construction industry. Laborde and Sanvido (1994) also highlighted the importance of UEC according to their research results. It was found that students involved with internships were made aware of a variety of career opportunities. In addition, their engineering and technical knowledge was increased, their communication skills were improved, and they obtained more contacts for future employment (Croissant, Ogden and Ogden, 2000). Further, it was observed that some companies appeared to prefer hiring new employees who already had a co-op, internship, or other work experience within the company (Koehn, 2004). Smith, et al. (2018) also noted that Industry-University Partnerships can facilitate students developing a more holistic perspective on Corporate Social Responsibility and the socio-technical nature of professional engineering practice. On the other side, experienced professionals from industry should actively participate in university education as visiting faculty members, or by sponsoring undergraduate design teams, by organizing live field visits for students, and by co-supervising projects and graduate dissertations. Industry could also provide sponsorship of R&D projects in universities, offer financial support to help the universities conduct research projects, which were of potential benefit to the industry and fund more scholarships to graduate students. Collaboration

between universities and industry across a variety of mechanisms, will also benefit the improvement of academic and professional programs through learning industry-led practices (Toor and Ofori, 2008).

In existing UEC publications in China, most of the research focused on analyzing the benefits of this model, which is based on the excellent knowledge source that companies may provide. UEC is an important mechanism to enhance the general competence, practical application skills and innovation capability of engineering graduates in modern university education (Yang, Zhang and Wu, 2017). As one of the important forms of cooperation between the university and industry, UEC is a win-win mode for both the universities and companies, since on one side, it will benefit the university to improve the general quality of their graduates, and on the other side, it will help the company select the right graduates they need in a more efficient way. Hence, UEC is an effective model to cultivate excellent engineering and management graduates, and as a result many universities and educators in China, as well as across the world, pay special attention to UEC in modern education (Li, Li and Lu, 2015). In educating excellent construction engineers and managers, the companies have the resources which universities do not possess. For example, they are sensitive to the development trend of construction market, understand more comprehensively the market requirements and demands of the engineering graduates, have advanced equipment and manufacturing technology, have numerous experienced engineers and technicians, have a real-world engineering practice and innovation environment and establish a special enterprise culture (Lin, 2013b). All these ingredients are very helpful to improve the working capability and general competence of construction management graduates. Practical learning based on real-world projects can significantly improve the learning performance, such as better understanding of the topic and theory, improvement of problem analyzing and solving capabilities, communication skills, innovation capability and accumulation of real hands-on experience (Liu, et al. 2012). Therefore, the universities which offer construction management programs should consolidate their education base through cooperation with suitable companies, to create a better environment of educating future competitive construction management graduates.

In UEC field, very few studies were conducted on analyzing the research status in Chinese journals and most of them were published 5 years ago. For example, Yi, Wen and Chen (2014) utilized UEC articles published in Chinese education journals from 1992-2011 to review the importance of UEC, reform of the university management practice in UEC process, meaning of UEC, UEC models and operation mechanism of UEC. Zhang, Yin and Chen (2013) used the UEC literature published in CNKI database from 2000-2011 to identify the research topics of these articles. The two papers also summarized the weakness of past research results and proposed the research directions for UEC. In addition, all the existing literature review articles on UEC adopted qualitative approach which is based on the analysis of limited number of research publications. Fellows and Liu (2008) noted that, in qualitative content analysis, the emphasis is to determine the meaning of data (for example grouping the data into different categories). However, the quantitative analysis extends this approach to produce numerical values of the categorized data, such as ratings, frequencies, and rankings, for further statistical analysis. As such, this study employed a quantitative method with the review of 300 high-quality journal papers to derive more comprehensive research findings.

Research method

In order to achieve the three objectives of this paper, a research framework similar to Zhang, et al. (2016) in reviewing the PPP research status was adopted. Generally, the research framework comprises the following three stages:

(1) **Stage 1:** UEC (*Xiaoqi Hezuo* in Chinese) were used as the search keyword to identify the journal papers published in CNKI database. In order to ensure the quality of publications, the papers selected for analysis were based on the download frequency in descending order of the papers published in the same year. Usually, the researchers in China rely on the classification of Class-A journals (well-known first-tier Chinese journals recommended by Peking University Library) to determine the quality of the paper in Chinese journals. However, in the ten-year period, the journals in the Class-A clusters have been adjusted every 3-4 years, which means some journals were in the Class-A clusters in 2013, but they were removed from the clusters in 2016. Hence, the download frequency of the papers was a reliable and straightforward standard to derive higher quality of research papers on UEC.

In addition, the relevance of the research topic with UEC was considered by the authors in screening the valid papers. After downloading the papers one by one in descending order following the download frequency, a quick review (i.e. a review of the title and abstract of the paper) was conducted to determine whether a particular paper was focused on UEC. If it was not related with UEC in education field, it would be removed from the valid sample. Then the next paper in the frequency sequence from the database was downloaded and quickly reviewed to determine whether this paper was suitable for further analysis.

(2) **Stage 2:** A brief review (i.e. a quick review of the overall paper, including the title, abstract, introduction and conclusion) was carried out to further determine whether the research topic of the paper was relevant with UEC and the general quality of the paper. The irrelevant and low-quality papers were also removed in this stage, and then the paper in the next frequency order would be included to get a final 30 valid samples each year for analysis. In total, 300 high-quality papers on UEC were finalized in January 2020, for further content analysis and statistical analysis.

(3) **Stage 3:** A comprehensive and in-depth review of the qualified UEC papers was conducted to identify the publication date, research topics, research findings and research methods adopted. During the overall research process, content analysis is the primary research method used in this study. Fellows and Liu (2008) argued that content analysis was frequently adopted to determine the major facets of a set of data by simply counting the number of frequencies that an activity happened or a topic was illustrated. Both qualitative and quantitative content analysis methods were adopted in this research. According to Fellows and Liu (2008), in qualitative content analysis, the focus was to determine the meaning of the data (i.e., grouping the data into different categories), whereas quantitative content analysis focused on generating the numerical values of the categorized data for the following statistical analysis. Based on this result, a comparison can be conducted and hierarchies of categories can be illustrated. In terms of qualitative content analysis, this study concentrated on the identification of research topics, research findings and research methods of a specific paper. While quantitative content analysis was based on the qualitative results to statistically categorize and count the identified results, with the assistance of MS Excel software.

Based on the above research process, the overall status of UEC research was mapped and analyzed in China.

Chronology of UEC publications

In order to understand the development trend of UEC research in the latest 30 years, the number of UEC publications (including the journal papers, reports, conference papers, MSc and PhD student's thesis), with UEC as the keyword, were derived from the CNKI database and categorized on a yearly basis. The result is shown in Table 1.

Table 1 Number of UEC publications from 1990-2019

NO.	1	2	3	4	5	6	7	8	9	10
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Number of publications	1	3	1	1	5	3	3	9	15	17
NO.	11	12	13	14	15	16	17	18	19	20
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of publications	48	38	58	87	166	200	417	651	1110	1475
NO.	21	22	23	24	25	26	27	28	29	30
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of publications	2025	2711	3233	3750	4012	4071	3857	3647	4078	4412

From Table 1, it can be found that since the first UEC publication in 1990 in China, the number of UEC publications experienced several rises and falls before 2001, whereas after 2002 the volume of publications has been increasing steadily, with only minor decreases in 2016 and 2017. Specifically, after 2007, the number of UEC publications has been rising significantly. However, this analysis is only for reference, since a frequent occurrence of irrelevant literature on the issue of cooperation between universities and companies were also included, without being discarded through the manual filtering process. According to the database, about 98% of the publications were journal papers, which generated about 35,100 pieces of potential papers on UEC topic. Since the analysis was conducted mainly through manual approach, review on the 300 sample papers was considered sufficient to generate a preliminary finding.

From the above development status of UEC research in Chinese publications, it appears that UEC research has become a "hot" topic in China in recent years, with strong promotion from the Chinese government and the active involvement by many universities and educators. During the last ten years, the Chinese government has highlighted the importance of UEC as an effective way to improve the general quality and practical working capability of university graduates and has taken many measures to promote the cooperation between the universities, companies and industry. Under this background, many universities and educators in China have actively utilized the high-quality resources of the companies to improve the quality of learning environment, through which the learning outcome and general quality of the graduates have been improved. The regulations/mandate issued by various Chinese government departments and specific requirements on UEC are summarized in Table 2.

Table 2 The regulations/mandate issued by Chinese government departments and specific requirements on UEC

Year	The regulations/mandate	The specific requirements on UEC
2007	The Ministry of Education and the Ministry of Finance jointly issued a guidance on the implementation of the “undergraduate teaching quality and teaching reform project of higher education”	It stated that the students’ practical working skills and innovation spirit should be significantly enhanced; and the practice base in the company should be developed for the students; to offer the students more practice and internship opportunities.
2007	The Ministry of Education issued a brief guidance on the further reform of undergraduate teaching to improve teaching and learning quality in a comprehensive way	It stated that the close cooperation should be strengthened between the universities and companies for teaching and research, and the students’ practice and internship platforms should be expanded, with the support from the companies and institutions in the joint development of practice centre.
2008	The Ministry of Education issued a guidance on the reinforcement of implementing the “quality project” for undergraduate specialty discipline development	It stated that the university should actively conduct practical training and social practice activities.....and explore the mode of learning with the cooperation between universities and companies.....and develop the students’ practice and internship bases with effort from the companies and industry institutions.....and explore new ways to develop lecturers with the joint effort from universities and industry. The university should actively promote the disciplinary lecturers to conduct research with the input from companies and industry and invite outstanding experts and senior managers in the industry as guest lectures to deliver university courses.
2010	Outline of the national medium and long-term educational reform and development plan (2010-2020)	To improve the quality of talent development, with the enhancement of skill-development laboratory, university and company practice bases.....to reinforce the development of practice capability through optimizing the practical training session. To establish a new mechanism of joint development for graduates with close cooperation between the universities, industry and companies.

Table 2 continued

Year	The regulations/mandate	The specific requirements on UEC
2015	General Office of the State Council issued a guidance on the reform of innovation and entrepreneurship education in universities and colleges	To explore new mechanism for graduate development through the university and university cooperation, university and company cooperation, university and industry cooperation, university and industry institution cooperation and international cooperation. To actively attract and use high-quality social resources and international education resources in the development of university graduates with innovative and entrepreneurial competence.
2015	The State Council issued a notice on the promotion of the development plan of first-class universities and disciplines	To establish a social participation mechanism in the education field, to optimize the close cooperation model between universities and companies as well as industry, and to promote the sharing of high-quality resources between the universities, institutions and social agencies, to form an effective cooperation mechanism.

Research topics of UEC papers in Chinese journals

Smith, et al. (2018) research findings indicated that UEC can take various forms, can be initiated at different stages of undergraduate/postgraduate education, and might be an efficient and effective approach, to exposing students to practices and policies that they might not otherwise be exposed to at traditional university education. Based on literature review results, it was found that the primary types of UEC were course development, practice resource development, lecturer practical skill development and joint research (Tener, 1996; Toor and Ofori, 2008; Shapira and Rosenfeld, 2011; Smith, et al. 2018).

The theme of *course development* means that the university and company may jointly develop disciplinary curriculum, course outline, new disciplinary course and new disciplinary reference learning materials. As Arif, et al. (2010) highlighted more input in current academic programs from industry was necessary. The university may also invite experts from companies as guest lecturers to deliver lectures to the students or to jointly supervise the undergraduate/postgraduate course design or dissertation with university lecturers. The involvement of practitioners is paramount since the traditional faculty might lack the depth and breadth of practical project judgment and experience that professionals in business and industry tended to possess (Kerkes, 1995). Hence, within this approach, the valuable intellectual resources, e.g. the management/working experience of the expert from the company, is effectively utilized in the learning process.

As to the theme of *practice resource development*, the companies either donate funding to develop laboratories at university or provide internship/part-time working opportunities to

the university students, to create a better practical learning environment for the students. Taking Purdue's CEM programme as an example, in addition to the value of the students' practical experience itself, the three 12-week internships provided the students a solid basis for approaching the academic work in the classroom (Tener, 1996). Those networking with the industry also helps the engineering graduates find employment and the engineering and/or construction firms recruit new engineers who are best suited to their specific needs (Shapira and Rosenfeld, 2011). Practice at Lamar University in USA also showed that being involved with cooperative, part-time and summer work experiences, the undergraduate and graduate students believed that three areas have been significantly enhanced with engineering work, including structural engineering, project management/scheduling and estimating, and teamwork (Koehn, 2004). In summary, students benefited significantly from being exposed to professional engineering environments in terms of increasing their engineering and technical knowledge (Croissant, Ogden and Ogden, 2000).

In terms of the theme of *lecturer practical skill development*, the companies either provide part-time working opportunities to the university lecturers or real-world cases and lessons learned in the management/production process, to develop the practical working capabilities and improve the up-to-date sense of industry awareness of university lecturers. Shapira and Rosenfeld (2011) highlighted that construction academics should not isolate themselves in the "ivory tower". Instead, they should regularly visit construction sites and meet with construction professionals. The site visits and discussions with practitioners complemented the faculty members' practical experience and generated a better understanding of current issues.

Under the theme of *joint research*, the university lecturers and industry experts collaboratively conduct research on specific topics, which might be funded by the companies or by the government or universities or other agencies/departments. Arif, et al. (2010) noted that industry-funded research was beneficial. However, in order to foster industry to be actively involved, academic institutions should also prove that they can conduct quality research projects. Frequent access to construction sites facilitated the collection of practical research data and led to a more comprehensive understanding from the academics on the research topics. In order to sustain this type of UEC, researchers should reach out to the industry beyond purely academic audiences and learn to communicate their ideas with construction professionals using the common language of the construction industry (Shapira and Rosenfeld, 2011).

In the content analysis process, the research topics of each UEC paper were identified and then statistical analysis was conducted. The results were shown in Table 3.

Table 3 Research topics of UEC papers in Chinese journals

Year	Item	Course development	Practice resource development	Lecturer practical skill development	Joint research
2010-2014	Number of topics	128	56	28	27
	Percentage	53.56%	23.43%	11.72%	11.30%
2015-2019	Number of topics	106	54	30	13
	Percentage	52.22%	26.60%	14.78%	6.40%

Table 3 continued

Year	Item	Course development	Practice resource development	Lecturer practical skill development	Joint research
2010-2019	Number of topics	234	110	58	40
	Percentage	52.94%	24.89%	13.12%	9.05%

Note: most of the papers have more than one research topic.

It can be found from Table 3 that course development (52.94%) was the most popular research topic in UEC field, followed by practice resource development (24.89%), lecturer practical skill development (13.12%), and joint research between the universities and companies (9.05%), in the last decade. This might also imply that course development and practice resource development are the most popular forms of UEC in China. Comparing the two five-year periods, the research topics only have slight changes in terms of the percentage of each UEC topic. In contrast, Smith, et al. (2018) argued that although a variety of industry-university partnerships existed, perhaps the most common type to date were internship and co-op programs, as well as industry-sponsored student design projects. In addition, Lamancusa, et al. (2008) also noted that industry sponsored student design project was a successful model for collaboration between the industry and university in the United States and internationally.

Research methods adopted by UEC researchers in China

In the construction management field, four typical research methods have been frequently adopted by researchers: *literature review*, *case study*, *interview* and *questionnaire survey* (Tang, 2011).

Literature review is a typical research approach to facilitate researchers understanding the development trend in the research area. Literature review is not only about reading research publications on a specific topic, but rather about presenting critiques of current research achievements to identify knowledge gaps (Yeung, 2007). The objectives of using *case study* approach is to identify or attempt to identify different interactive processes, or to identify the unique and common features, and to present how they affect the implementation of systems (Tang, 2011). The *interview* method is very popular in the construction management field to collect first-hand empirical data, which includes structured interview, semi-structured interview and unstructured interview (Tang, 2011). In *questionnaire survey* approach, the respondents' viewpoints are obtained with the same and standard questions using a pre-designed survey instrument. This approach is generally considered as one of the most frequently adopted methods in the construction management research area (Chow, 2005).

In the content analysis process, it was found that two additional methods (i.e. modelling and comparison) were also employed by Chinese UEC researchers. As to the *modelling* method, it refers to validating a particular UEC research topic through a model verification process based on Structural Equation Modelling (SEM) and Analytic Hierarchy Process (AHP) among others. Furthermore, *comparison* is a simple but effective approach to generate powerful and rigorous conclusions (Zhang, et al. 2016).

Based on the content analysis results, various research methods used in UEC literature are summarized and shown in Table 4.

Table 4 Number of research methods adapted by UEC papers

Year	Item	Elaboration	Case study	Comparison	Modelling	Questionnaire survey	Literature review	Interview
2010-2014	Number of research methods	95	26	7	13	12	5	2
	Percentage	59.75%	16.35%	4.40%	8.18%	7.55%	3.14%	1.26%
2015-2019	Number of research methods	84	42	14	6	7	8	1
	Percentage	52.17%	26.09%	8.70%	3.73%	4.35%	4.97%	0.62%
2010-2019	Number of research methods	179	68	21	19	19	13	3
	Percentage	55.94%	21.25%	6.56%	5.94%	5.94%	4.06%	0.94%

Note: some papers adopted more than one research methods.

The analysis results showed that the majority (93.00%) of the papers employed only one research method in the last decade among the 300 UEC papers. The elaboration research method was adopted by more than half (55.94%) of UEC papers, followed by case study (21.25%) and comparison (6.56%). In the two five-year periods, there is no significant change on the research methods adopted by UEC researchers in China.

Elaboration, which is commonly used in the construction management research field in China, refers to narrate, discuss, or depict the study without using other methods to support or validate the research findings (Zhang, et al. 2016). In the construction management field, adopting more research methods might rigorously validate the research findings, which makes the study more convincing (Zhang, et al. 2016). From this point of view, improvements should be made for Chinese researchers to employ a variety of research methods in a single-research-method paper in the UEC field.

Conclusion

UEC in China as well as internationally, was advocated as an efficient and effective way to bring students and faculty staff to the day-to-day practical activities and internal working practice of industry and enhance their understanding of the development status of the industry (Smith, et al. 2018). UEC might take a variety of forms, such as course development (e.g. industry-sponsored student design project), practice resource development (e.g. internship and co-op programs for students), lecturer practical skill development (site visit access provided by the industry to the lecturer) and joint research (e.g. research collaborations between the faculty and industry). In China, the government has placed emphasis on the application of UEC in improving the competence of graduates. In overseas institutions, since the early 1900s, engineering schools have actively promoted UEC as a way to engage students, faculty members and construction professionals in collaboration, which resulted in better trained engineers, generate research outputs that were relevant to the industry practice, and offer research and development benefits to companies (Koehn, 2004). Many educators in the construction engineering field and construction industry frontiers realized that it was valuable to establish effective industry-university working partnerships. By considering the construction industry as their customer and by collaborating with construction professionals on matters influencing the undergraduate/postgraduate program, the university faculty can improve

and sustain the quality of the educational program (Tener, 1996). However, collaboration between the university and company/industry is not straightforward and simple. The style of functioning, the motivations, the expectations, along with the difference in the ultimate goals of both parties, results in a challenge with bringing them together (Arif, et al. 2010).

With strong promotion from the Chinese government from 2007, publications on the UEC have been steadily increasing in the last decade. This study aims to map the overall research status of UEC publications in China and identify the most popular research topics under UEC theme and the most frequently adopted research methods in the publications. Three hundred high-quality journal papers on UEC were derived from 2010-2019 for statistical analysis, based on the result of both qualitative and quantitative content analysis.

It was found that since the first UEC publication in 1990 in China, the number of UEC research outputs experienced both rises and falls before 2001, whereas after 2002 it has been increasing steadily. Specifically, after 2007, the number of UEC publications has been rising significantly, with only minor decreases in 2016 and 2017. Course development (52.94%) and practice resource development (24.89%) were two of the most popular research topics in the UEC field from 2010-2019, which might also imply the potential application opportunities in practice. As to the research methods adopted by UEC researchers in China, more than half (55.94%) of UEC papers employed the elaboration method, followed by case study (21.25%) and comparison (6.56%) in the same period. These findings address the knowledge gap in the existing UEC literature, and present a practical contribution, since this study may help universities, which offer construction management programs, understand the general development status of UEC in China and globally, and take effective measures to strengthen their partnership with companies. In addition, the review on the UEC application and theory development status may also be a valuable reference for researchers to embark on relevant research in the future.

Several limitations exist in this study, which deserve future research in this field. Although a brief review of the overall paper was conducted in the data collection process when determining the quality of a specific paper, the 300 sample papers may not be the best quality in the last decade, since the authors primarily followed the principle of descending order of download frequency, as the threshold to determine the quality of papers with subjective evaluation process. This also means that high-quality papers with lower download frequency may not be included in the investigation. On the other hand, with comparison to the large amount of UEC papers published in the same period, the 300 sample papers may not represent the overall status and development trend of UEC research in China. In future research, more high-quality UEC papers will be analyzed to derive more comprehensive findings.

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