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Research Article

Establishment of the Practical Education System for Civil Engineering Majors in Local Colleges and Universities under the Emerging Engineering Background*

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Abstract

With the gradual advancement of the "trilogy" for the construction of emerging engineering disciplines in China, local universities and colleges should proactively explore the education system for civil engineering majors in line with the development of emerging engineering disciplines, so as to cultivate practice and innovative civil engineering professionals who catches up with the fast-changing times. In this paper, a “six-collaboration” model was proposed for the practical education of civil engineering majors in local colleges and universities, including “serial-parallel collaboration”, “radiation-type collaboration”, “campus-enterprise collaboration”, “Internet collaboration”, “international collaboration”, and " agricultural characteristic collaboration”, which meets the requirements of the growth of "emerging engineering disciplines". Since the implementation of the "six-collaboration" practical education system, sound results have been perceived, for which this paper serves as reference for the development of the practical education system of local colleges and universities.

Keywords

Emerging Engineering • Civil Engineering • Local Universities and Colleges • Collaborative Mode • Practical Education

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In recent years, China has implemented major strategies such as (Hu, Feng, Han & Xu, 2017) "Innovation-driven Development" and "Internet+". Subsequently, the "trilogy" of new engineering discipline construction pulled down the curtain in turn, namely "Fudan Consensus", "Tianda Actions" and "Beijing Guide". On March 15, 2018, the General Office of the Ministry of Education announced the first national "emerging engineering" research and practical projects, with a total of 612 projects included. The civil engineering, architecture, water conservancy and marine reform projects account for 8.5% of professional reform projects and 5.7% of the total reform projects. The new engineering construction mainly refers to (Lu, Yang, Ding & Zhou, 2018) the new concept, the new structure, the new model, the new quality, and the new system. Since then, the reform of the new engineering disciplines has been vigorously carried out in China.

Status of practical education of civil engineering majors

Since the 21st century, from the traditional point of view, colleges and universities generally pay insufficient attention to the cultivation of engineering practice ability (Li *et al*., 2016). In this context, the National Ministry of Education issued the "*Several Opinions on Further Strengthening Undergraduate Teaching in Colleges and Universities*", clearly stating that it is essential to vigorously strengthen practical teaching and effectively improve the engineering practice ability of college students. Li *et al*. (2016) gave an analysis of the status quo of civil engineering practice teaching in China, and expressed their views on the insufficient practical experience of teachers and integration of major characteristics and social demands in practical education. The study by Li, Du, Xue & Gao (2013) show that the United States attaches great importance to students' practical ability, so do Germany, France, and the United Kingdom (Li *et al*., 2016). In contrast, China demonstrates insufficient emphasis on the practical teaching, imperfect practical teaching system, unstandardized organization and implementation of practical education, unsatisfying practical teaching conditions, and poor novelty and correlation of practices (Li *et al*., 2016).

Establishment of engineering practical education system for civil engineering majors in agricultural universities and colleges

Deficiencies in existing civil engineering education of the university

Through previous employer feedback and follow-up survey of graduates, it is found that practice teaching for civil engineering majors in the author's university is facing the following problems. Firstly, the practical teaching is partially disconnected to the industrial development, mainly referring to few practical teaching courses set and poor connection between the practice theme and actual engineering demands. Secondly, the internship base, due to incomplete facilities, cannot work as a sound practice mechanism. Thirdly, the practice teaching system is imperfect without enough teaching control and guarantee. Fourthly, the practices are not closely related. Fifthly, the Internet is not fully utilized. Sixthly, the practice teaching does not take the university's characteristics into account. All these have seriously affected the quality of professionals trained.

Establishment of the engineering practical education system for civil engineering majors

The civil engineering majors in the author's university consist of undergraduate civil engineering, structural engineering for academic masters, and architecture and civil engineering for professional masters. During the establishment of the practical education system, all graduates and current students in the period from 2016 to 2018 were involved. The project team established the practical education system following the "six-collaboration" model for civil engineering majors.

"Series-parallel collaboration" of the practice course modules. The practice modules of professional education are determined by the professional course sequence, namely the experimental teaching module, curriculum design module, graduation project module, and innovation module. The changes in the practice of each module are shown in Table 1-3.

Table 1
Changes in the Courses of the Experimental Teaching Module

No.	Course	Credit hours (variation)	No.	Course	Credit hours (variation)
1	Material mechanics in-class experiment	10 (+25%)	8	Aseismic building structure design test	4 (newly added)
2	Engineering measurement in-class experiment	16 (0%)	9	Civil engineering professional test course	16 (266%)
3	Engineering geology in-class experiment	16 (newly added)	10	Structural design software experiment	10 (0%)
4	Soil mechanics in-class experiment	6 (0%)	11	Computer aided design (CAD) in-class experiment	14 (-30%)
5	Civil engineering materials in-class experiment	12 (+20%)	12	Structural test (academic master)	6 (newly added)
6	Concrete structure principle in-class experiment	4 (0%)	13	Geotechnical Engineering Test (professional master)	32 (newly added)
7	Project budgetary in-class experiment	8 (newly added)			

Table 2
Changes in Practice Weeks of the Curriculum Design Module

No.	Design	Weeks (variation)	No.	Design	Weeks (variation)
1	Housing architecture curriculum design	1 (0%)	5	Civil engineering construction course design curriculum design	1 (-33%)
2	Concrete structure principle curriculum design	1 (-33%)	6	Project budgetary curriculum design	1 (newly added)
3	Steel structure curriculum design	1.5 (0%)	7	Basic engineering	1 (0%)
4	Concrete structure design curriculum design	2 (+100%)	8	Aseismic building structure design curriculum design	1.5 (+50%)

Table 3
Changes in the Practice Weeks of the Comprehensive Internship and Graduation Project Modules

No.	Internship	Weeks (variation)	No.	Internship	Weeks (variation)
1	Measurement internship	2 (0%)	5	Civil engineering production practice	1 (newly added)
2	Engineering Geology Internship	1 (newly added)	6	Graduation internship	2 (-50%)
3	Cognitive internship	1.5 (+50%)	7	Graduation Project	14 (+8%)
4	Production Practice	2 (newly added)			

The innovation module is realized mainly through participation in innovative activities, such as: BIM competition, Zhou Peiyuan Mechanics Competition for College Students, structural design competitions, "Challenge Cup" National Series Science and Technology Academic Competition for College Students, and innovation and entrepreneurship projects below national level.

The inter and intra-module horizontal and vertical links of civil engineering practices are thoroughly explored to put forward the “serial-parallel" collaboration mode practice, mainly reflected in the comprehensive designs and comprehensive experiments. The two are in series with each other and in parallel internally, as shown in Figure 1.

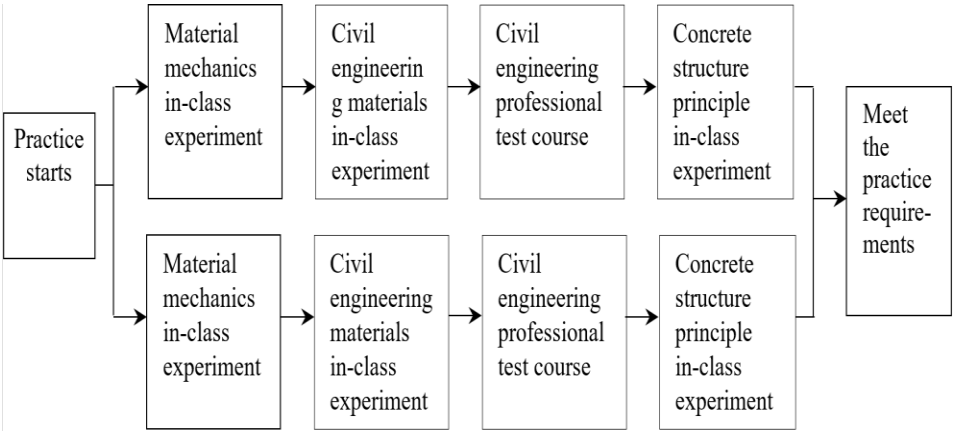

Figure 1. "Series-parallel" collaboration

"Radiation-type collaboration" of the practical education system. The "radiation-type collaboration" centering on the practical teaching of civil engineering majors in the author’s university is as follows.

(1) The university should strengthen exchanges and cooperation with the same or related majors within and outside the campus, establish an innovation and entrepreneurship center, provide necessary platforms, funding, rewards and professional titles, create an exchange channel, formulate innovative and entrepreneurial training programs for students, cultivate teachers and students' innovation awareness, establish corresponding systems for the hosting, organization and management of various innovative and entrepreneurial activities, and develop

corresponding documents and management mechanisms.

It is mainly done by setting up various competitions that are attended by two or more majors within the university and among universities. For example, the BIM competition is attended by several majors such as housing architecture, water supply and drainage engineering, civil engineering, and engineering management; architectural and structural design competitions involve housing architecture, civil engineering, engineering management, agricultural water conservancy engineering, water conservancy and hydropower engineering, and urban planning; Zhou Peiyuan Mechanics Competition for College Students can be held by different universities and colleges in turn for all majors to participate in; students are encouraged to participate in the joint graduation project competition, engineering drawing contest, and mathematical modeling contest among many universities.

(2) Strengthen communication with other universities

It is realized mainly through academic and technical exchanges. First of all, domestic and foreign experts and industry elites, at least five annually, are invited to the campus to make presentations or exchanges with teachers and students, with special funds prepared by the annual fiscal plan and certain system set. Secondly, some students are organized to participate in academic conferences at home and abroad every year to make sure one-third of master students and one-twentieth of undergraduates can participate in field exchanges in the past three years. In the future, the university should continue to increase exchanges with the outside world, and strive to establish long-term relationships with foreign universities for joint training in addition to increasing the proportion of students engaged in external projects and exchanges.

(3) Develop A Win-win Research Pattern of Maters Leading Undergraduates

Master students leading undergraduates in scientific research, on the one hand, improves the ability of undergraduates to research and innovate, and on the other hand, speeding up research by undergraduates serving as assistants. In terms of the proportion of personnel, the ratio of master students to undergraduates of 1:2 is ideal. In the specific practice, at the beginning of the fall semester each year, master students in the first year of study and sophomores follow a two-way selection policy, which will last to the graduation of both sides.

Mutually benefiting "Campus-enterprise Collaboration" (mainly on campus-enterprise cooperation). First of all, the practice link of campus-enterprise collaboration is set up, and then the two parties sign a contract after agreeing on the agreement. The contract mainly includes the status, tasks, rights, responsibilities and obligations of both parties. Both parties must set up a special organization, and ensure the effective implementation of collaborative training by a collaborative training plan formulation, organization and implementation, inspection, evaluation, feedback, and the revised PDCA cycle principle. Secondly, the university should establish a campus-enterprise collaborative practical curriculum system, clarify the requirements for corporate teachers (such as first-class registered architects, structural engineers and cost engineers, etc.), formulate teaching norms, and clarify the practical content, time and assessment methods for full-time teachers and corporate teachers. Under the premise of the corporate teachers with general civil engineering skills, enterprise teachers in agricultural industrial parks or beautiful villages are indispensable. The undergraduate-postgraduate collaborative training practice courses are shown in Table 4.

Table 4
Practices in the Undergraduate-Postgraduate Collaborative Training

Item	Civil engineering undergraduates	Civil engineering postgraduates (academic master)	Architecture and civil engineering postgraduates (professional master)
1	Cognitive internship	Professional practice or teaching practice	Professional Practice
2	Production internship	Make research report	Listen to academic reports
3	Civil engineering production internship	Make academic report	Make research report
4	Graduation internship		6 or 12 months of production practice in enterprises
5	Graduation project		

Establish "internet collaboration" consisting of "integrated pipe corridors connected by multiple-directional networks". Combine civil engineering with the Internet to establish an "Internet collaboration" consisting of a "multi-directional network-connected integrated corridor":

(1) Establish a complete online practical course based on the on-campus curriculum platform. The online course includes a courseware library, a common video library, a photo library, a micro video library, etc.

(2) Establish a virtual simulation laboratory based on the building information model BIM and take into account other aspects of virtual simulation technology, such as VR, with teaching sessions added such as flipped classrooms, MOOCs, and virtual simulation technologies.

(3) Add a column for civil engineering majors on the college website, including the innovation and entrepreneurship column, industry website link column, industry norms and procedures column, industry enterprise introduction and job search column, inter-university management corridor, academic exchanges and reports column, practice standard management corridor, results display channel, and graduation project management platform.

(4) Establish an open laboratory

It mainly includes:

1) Establishing a multi-content, multi-level and intersected open laboratory

The multiple contents are mainly reflected in postgraduate research and experimental courses, undergraduate experiments, national and below-level innovation and entrepreneurship researches, various types of competitions. The multiple levels are mainly reflected in the levels of teachers, postgraduates, undergraduates and social aspects. The intersection is mainly reflected in the intersection of the three levels of teachers, postgraduates and undergraduates, and the intersection of multiple contents at the social level.

2) Establishing a laboratory platform and forming a management mechanism.

Establish an open laboratory platform, as shown in Figure 2.

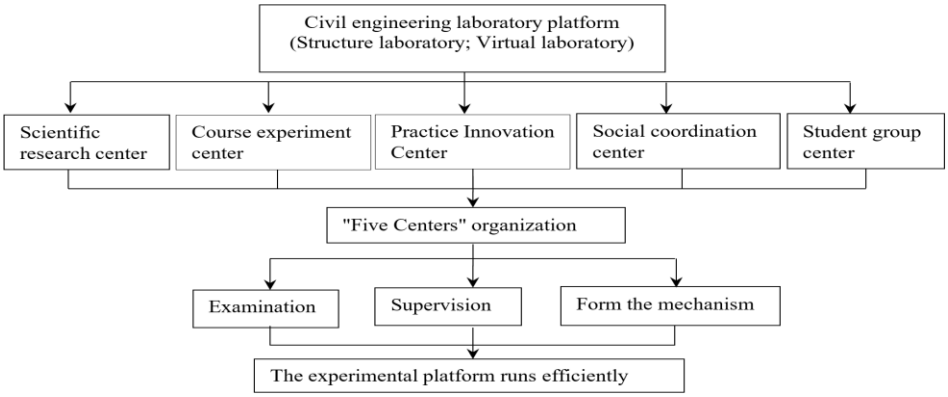

Figure 2. Composition and operating mechanism of the civil engineering experimental platform

"International Collaboration" represented by engineering certification education and iso9000 quality standard system. The engineering practical education system for civil engineering majors is established based on the engineering certification education and ISO9000 quality standard system, reflecting the "international collaboration". Table 5 shows the comparison of the practice links with and without the engineering certification education and the ISO9000 quality standard system as reference. The framework of the standard is shown in Figure 3.

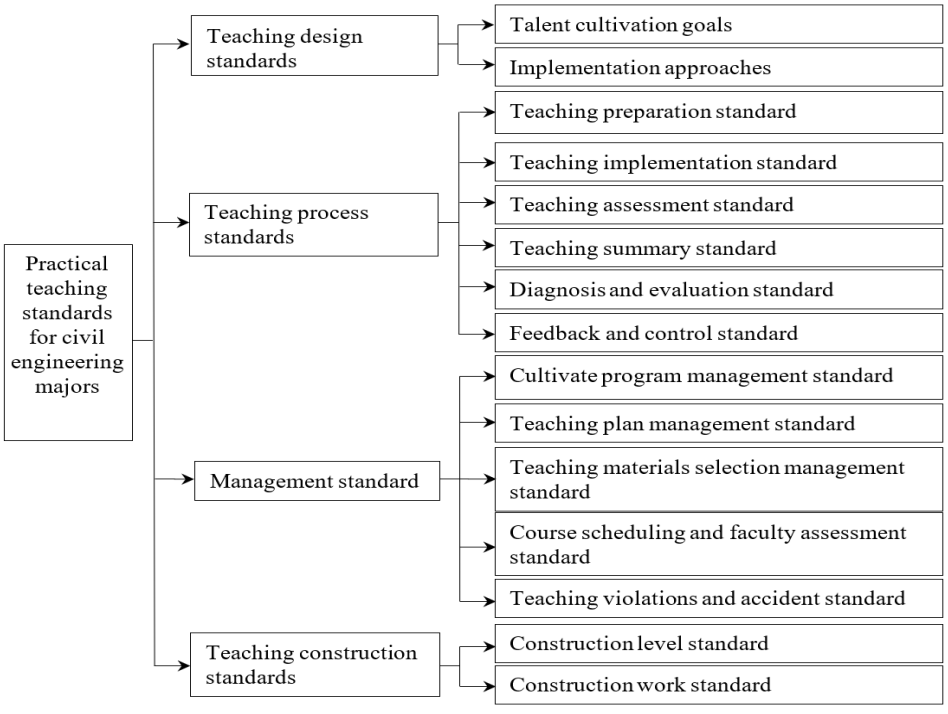

Figure 3. The framework of practice teaching standards for civil engineering majors

Table 5
Comparison of Practice Links with and without Engineering Certification Education and ISO9000 Quality Standard System as the Reference

Item	With the reference	Without the reference
Reference standards or documents for practice links	Guiding professional norms for civil engineering undergraduate courses in higher education institutions, civil engineering professional assessment (certification) documents for national colleges and universities; ISO9000 quality standard system; documents and plans for civil engineering majors training of the university and other universities	Documents and training programs of the university and other universities for civil engineering majors
Practice link setting	The credit hours of practical curriculums are increased with higher proportion, more in line with professional norms.	Few practice courses are set with few credit hours.
Practice link management	A complete set of practical system management organization and specific standards for practical teaching are established, with comprehensive and specific standards and provisions for practical teaching management, and the implementation preparation, process, inspection, supervision, improvement, punishment.	The practice system management organization is not complete, with incomprehensive and unspecific practical teaching standards.
Corporate participation in the practice links	A special practice base is set up, and the practice links that are specifically attended by corporate teachers are stipulated, which closely links engineering practices with related companies and engineers.	There is no special practice teaching base, and few enterprise personnel are invited to guide the practice, resulting in lack of close relations of engineering practices to enterprises' requirements.
Practice platform establishment	The practice platform consists of a physical platform and a virtual platform, including one national platform and one provincial platform.	No established platforms
Teachers in practice links	Full-time teachers of the university and corporate teachers	Full-time teachers on campus
Students' benefits from practice links	Students' practical ability has been greatly improved.	Insufficient practical ability of students

"Agricultural Characteristic Collaboration" by increasing the practice links related to agriculture. The development of civil engineering majors in agricultural engineering colleges and universities should also have its own characteristics while considering the alike growth with other institutions, namely "agricultural characteristic collaboration". Details can be seen as follows:

1) Explore the connotation of existing scientific research topics, and combine with the civil engineering practice links by "campus-enterprise collaboration", "Internet collaboration" and "radiation-type collaboration" on the basis of the original topic of green, lightweight and high-strength construction materials.

2) Add practical teaching links such as assembly structure and energy-saving integration of building structure. For example, in the cognitive internship, the university can add specific internship sectors, such as the assembly structure of modern agricultural industrial parks, building structure energy-saving integration, prefabricated component factories, and concrete mixing stations;

3) Establish a virtual simulation laboratory based on the building information model BIM, and enhance the theoretical foundation and practical ability of students through trainings of the assembly structure, practical engineering, complex structure, and complex engineering required in several competitions to further expand their knowledge and quickly learn new technologies and skills.

Effect Evaluation

Since the establishment of this system and implementation for civil engineering majors in the past three years, major results have been perceived. Details are shown as follows:

(1) Specific achievements

The achievements of the courses established in the past three years are shown in Table 6. The awards of the innovation and entrepreneurship projects are shown in Table 7. The number of teaching research achievements is shown in Table 8.

Table 6
Course Achievements

Category of achievements	Practice courses	Teaching standards of single practical course	Number of practical teaching norms	Practical teaching standard system
Number of achievements	73	73	73	1

Table 7
Innovation and Entrepreneurship Achievements

Category of achievements	Provincial innovation and entrepreneurship projects	Provincial competition awards	University-level competition awards
Number of achievements	1	3	6

Table 8
Teaching Research Achievements

Category of achievements	National projects	Provincial awards	Provincial projects	University-level awards	University-level projects	Papers on teaching
Number of achievements	2	2	2	1	3	5

(2) Higher Employers' Satisfaction with Graduates' Practical Ability

Through the tracking records of some undergraduates and postgraduates who have graduated from 2016 to 2018, it is found that the employers' satisfaction with the graduates' practical ability, team awareness and innovative spirit is increasing year by year, as shown in Figure 4.

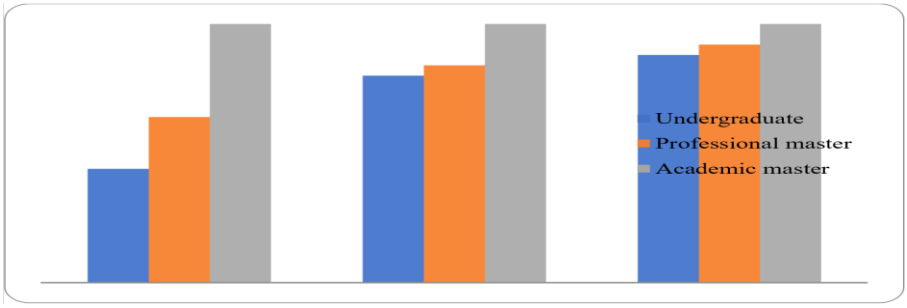

Figure 4. Survey on practical ability satisfaction

(3) Better Employment of Graduates

Through the survey on some undergraduate and postgraduates of civil engineering majors who have graduated from 2016 to 2018, it is found that the graduates are enrolled by higher-level employers. See Table 9 for details.

Table 9
Survey on Graduates' Employment Level

Year	Undergraduate		Professional master		Academic master	
	Construction enterprises	Design enterprises	General enterprises	Large enterprises and universities	General enterprises	Large enterprises and universities
2016	100%	0%	61.5%	38.5%	50.0%	50.0%
2017	94%	5.1%	45.5%	54.5%	45.5%	54.5%
2018	89.5%	10.5%	46.7%	53.3%	40%	60%

(4) Students' Satisfaction with Their Practical Ability

In June 2018, the questionnaire was designed for the practical effect of the practical teaching system and delivered to the undergraduate and postgraduate students of civil engineering in 2015, 2016, and 2017. It turns out their satisfaction level reaches 100%.

Conclusion

According to the requirements of enhanced researches and practices by the development of emerging engineering disciplines, the “six-collaboration” model practical education system for civil engineering majors in universities and colleges was established as the initial exploration. Specifically, the “serial-parallel collaboration” embodies the concept of life cycle and curriculum cross-integration education, which promotes the close cross-collaboration between students of different grades and teachers of different curriculum groups, and enhances students' practical ability and innovative ability. The "radiation-type collaboration” contributions to the exchanges and collaboration between the same and different majors inside and outside the university and country centering around the university's civil engineering majors. The "campus-enterprise collaboration" greatly improves students' practical ability by the introduction of corporate strength into practical ability training. The "Internet collaboration", by combing civil engineering majors and the Internet, makes it easier and faster for students to learn, practice, and find jobs. It has solidified practical knowledge, broadened horizons,

extended study time and improved practical ability of students. The "international collaboration" is in line with "learning from international experience to develop emerging engineering disciplines" in Fudan Consensus and "focus on guidance by concepts and quality assurance" in Beijing Guide. The "agricultural characteristic collaboration" is integrated with the agriculture university's conditions based on the general practical skills required for the civil engineering majors to form the teaching model of the university's own characteristics to meet the classified advancement requirements. Since the implementation of the "six-collaboration" practical education system, outstanding achievements have been made, for which the system can serve as reference for the development of the practical teaching system in local universities and colleges.

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