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What core competencies should a great engineer possess? A comparative study from the perspective of engineering undergraduates in China and the United States

Yi Liu, Yintai Xiao*, Xueming He

Higher Education Research Center, Northwestern Polytechnical University, Xi'an 710072, Shaanxi Province, China.

ABSTRACT

Excellent engineers are an important strategic talent force of the country. studying its core competencies and development status serves as the critical foundation for the cultivation of these talents in the new era. One questionnaire for 2460 engineering undergraduates from a first-class university suggests that the core competence is comprised of knowledge, skills, and competence/ability/capacity. Students value basic knowledge including mathematics, physics, chemistry, and engineering science, while also attach great important to the skills to apply scientific engineering knowledge in practice, and the ability to self-motivate and inspire. Economic and business knowledge, leadership, curiosity and the desire to keep learning were the most lacking among students. By further comparing the core competencies of excellent engineers from the perspective of students from China and the United States. it is found that Chinese students highlight the mastery and application of basic knowledge, while American students value effective communication and leadership more. Chinese students value the ability to self-drive and motivation, whereas American students give priority to teamwork and the ability to work in multi-disciplinary teams. To cultivate excellent engineers in the new era, we should strengthen the integration of curriculum in engineering education, emphasize the learning of basic knowledge, expand students potential, forster students' active learning motive, and Create engineering practice scenarios, cultivate the core competencies of future engineers.

Key words: excellent engineer, core competency, engineering major, undergraduate students, china, united states

INTRODUCTION

In the contemporary epoch characterized by the ascendancy of the knowledge economy, the cultivation of exemplary engineers is inextricably linked to the nation's capacity for scientific and technological self-reliance and the overarching objectives of socialist modernization.[1] These engineers are expected to be imbued with a profound sense of patriotism,[2] possess the agility to align with the multifaceted demands of a diverse array of goals, and adeptly harmonize market-driven orientations with the strategic imperatives of the nation.[3] They must also be capable of reasonably matching the market orientation with national needs.[4] Concurrently, they must be equipped with a robust repertoire of digital skills,[5] a sine qua non for navigating the evolving landscape of the digital economy and its attendant expectations for a technologically adept workforce. Furthermore, an indomitable spirit of innovation is imperative,[6] one that deftly navigates the

***Corresponding Author:**
Yintai Xiao, Higher Education Research Center, Northwestern Polytechnical University, No. 127, West Youyi Road, Beilin District, Xi'an 710072, Shaanxi Province, China. Email: 204005472@qq.com; https://orcid.org/0009-0002-6683-2857
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delicate equilibrium between fostering domestic scientific and technological autonomy and engaging in fruitful international scientific and technological collaborations.

China, while boasting the most extensive scale of engineering education globally,[7] grapples with a constellation of challenges. Notably, the quality of engineers, though improving, remains comparatively suboptimal. A significant chasm exists in the cultivation of core and pivotal scientific and technological talents,[8] those crucial for surmounting the formidable barriers that impede advancements in key technological domains. Additionally, the engineering cadre's practical and innovative capabilities are underdeveloped, and their interdisciplinary and general literacy is alarmingly deficient.[9] In stark contrast, the United States stands as an internationally acclaimed powerhouse in engineering education, not merely as a major player but as a vanguard in the realms of educational reform, transformation, innovation, and development within the engineering discipline.[10] The United States has established itself as a paragon of excellence in the nurturing of engineers and scientific and technological talents, consistently ranking at the zenith of global standards.

Given this dichotomy, it becomes imperative to embark on a scholarly inquiry into the perceptions of students regarding the quintessential core competencies that define outstanding engineers. This study endeavors to elucidate the divergences in perspectives between Chinese and American undergraduate students concerning the core competencies requisite for engineering excellence. To this end, the study leverages the conceptual framework of core competencies to synthesize the requisite knowledge, skills, and abilities (KSAs) for engineers to excel. Employing a dual-methodological approach of questionnaire surveys and comparative analysis, the research delves into the composition and developmental trajectories of these core competencies as perceived by engineering undergraduates in both China and the United States, meticulously contrasting the divergent viewpoints. The culmination of this research presents a suite of strategic countermeasures and actionable recommendations, specifically tailored to enhance the cultivation of core competencies among the cohort of aspiring engineers in China.

RESEARCH METHODS

Data sources form American students

In 1893, the American Society for Engineering Education (ASEE) was established with the mission of advancing innovation, pursuing excellence, and conducting engineering education at all levels, with the aim of establishing authority in nurturing engineering professionals. Since the 1960s, ASEE has published a series of influential research reports, including *The Engineering Education Report (1968)*,[11] *The Green Report (1994)*,[12] and *Creating a Culture of Academic and Systematic Innovation in Engineering Education (2009)*.[13]

Notably, in its report *One of the Reports on the Transformation of Undergraduate Engineering Education: An Integrated and Industry Perspective (2013)*,[14] the Engineering Education Association conducted a comprehensive survey of enterprises. By synthesizing the views of the industry, the report highlighted a significant misalignment between current engineering education and industrial needs. It criticized colleges and universities for promoting and producing graduates without a thorough understanding of the foundational elements that shape an ideal engineering professional or considering the needs of the customer base. On this basis, the American Association for Engineering Education condensed the core competencies required for engineering activities, identifying 36 kinds of KSAs, and constructed a dual model of skills and professional quality required by T-shaped engineering graduates.

In 2017, ASEE released its follow-up report, Engineering Undergraduate Education Transformation Report II: Insights on Future Engineers.[15] This report invited undergraduate engineering students to participate in a survey to evaluate the importance of 36 KSAs for the engineering profession and to assess their universities' quality of education in these areas. A total of 165 questionnaires were distributed, and 134 valid questionnaires were recovered, resulting in an effective recovery rate of 81%. These data constitute the core competency dataset of American engineering undergraduates utilized in this study.

Data sources from Chinese students

Design of questionnaire items

Regarding the design of the questionnaire items, primary reference was made to one of the Engineering Undergraduate Education Transformation reports issued by the American Engineering Education Association. Specifically, the report titled *Comprehensive and Integrated Industry Perspective (2013)*[14] was consulted, which outlines the core competencies necessary for conducting engineering activities. The report posits that 36 distinct types of KSAs form the three foundational elements of the core competencies for outstanding engineers, creating a synergistic and mutually reinforcing relationship. Knowledge is identified as the bedrock for the cultivation and enhancement of literacy; without the requisite accumulation of knowledge, students are unable to internalize and elevate their psychological character to a higher plane.[16] Skills are characterized as the conduit through which knowledge is applied in practical settings, while abilities represent the external manifestation of literacy. It is only by translating knowledge into practice that students can truly master the corresponding accomplishments; ability, in this context, is the external expression of such mastery. To holistically enhance students' core competencies, emphasis must be placed on the development of social communication skills and the capacity to work and collaborate across different disciplines and domains.

Furthermore, inspired by the concept of the "T-Shaped Professional" introduced in the second section of the report, the questionnaire was crafted to explore students' views on the significance of "hard knowledge"(*e.g.*, mathematics, physics, chemistry, and engineering sciences),"soft skills"(*e.g.*, project management, leadership, effective communication), and "smart abilities"(*e.g.*, emotional intelligence, curiosity, self-motivation, and a desire for lifelong learning) within the engineering profession. Consequently, these data were compared with those from students in the United States. Ultimately, the core competencies of excellent engineers were delineated into 10 types of knowledge, 13 types of skills, and 13 types of abilities (Table 1). Based on the refined components of these core competencies for outstanding engineers, the "Questionnaire on Core Literacy of Engineering Undergraduates" was meticulously compiled.

Test for reliability and validity

First, the Cronbach's α coefficient was employed to estimate the internal consistency reliability of the questionnaire. The overall Cronbach's α coefficient for the entire questionnaire was found to be 0.981, and the α coefficients for each subscale were all above 0.88. This indicates that both the subscales and the total scale possess excellent internal consistency. Second, item analysis was conducted, and the results showed that the CR values for all 36 literacy components were significant and correlated. Consequently, all items were retained. Finally, exploratory factor analysis was performed. The results revealed that the KMO value was 0.985, and the Bartlett's test of sphericity reached a significant level ($P < 0.001$). This demonstrates that the data have a high degree of structural validity.

Sample schools and sample data

The dataset for this study was meticulously gathered from N University, a distinguished research-oriented institution with a focused mission on personnel training and scientific research in the domains of aviation, aerospace, and navigation. Throughout its 80-year history, N University has steadfastly prioritized the cultivation of leading talents, thereby establishing itself as a vital instrument of the nation. The university has been instrumental in training a significant number of outstanding engineers, providing robust support for the advancement of weaponry and equipment, enhancing the independent security and control capabilities of key core technologies in the defense sector, and contributing to the development of the western region. It is widely recognized as the "cradle of chief engineers". In an effort to deepen the reform of engineering education and expedite the construction of a world-class engineer training system with distinctive Chinese characteristics, the university was granted approval to establish the National Institute of Excellent Engineers. Against this backdrop, N University initiated a survey project on the core literacy of engineering undergraduates, with the aim of providing support for the university's accurate guidance and effective consultation for students.

In October 20, the university's Higher Education Research Center embarked on a survey targeting the core literacy of engineering undergraduates. A total of 5563 students from 7 out of the 22 engineering departments at N University were selected as samples, utilizing a combination of online questionnaires and cluster sampling methods. The survey garnered a total of 2521 completed responses, yielding a response rate of 45.32%. After rigorous data cleansing, the final dataset comprised 2460 valid responses, with an effective response rate of 97.58% (Table 2).

RESULTS

The core competency of engineering undergraduates in China

Evaluation of 10 kinds of knowledge by Chinese engineering undergraduates

Upon analyzing the mean values of the ten types of knowledge, it is evident that the three categories of knowledge that students deem most critical for engineering professions are as follows: mathematics, physics, chemistry, and engineering science (hereinafter collectively referred to as "basic knowledge"); knowledge of systems integration; and knowledge of ethical integrity and scientific and technological responsibility. Notably, these three areas are also perceived by students as being most effectively taught within their respective majors (Table 3). Specifically, 50.24% of students expressed "very satisfied" sentiments regarding the instruction of basic knowledge, 4.6% towards the teaching of knowledge related to moral integrity and scientific and technological responsibility, and 38.41% concerning the knowledge of systems integration. Conversely, a mere 1.14%, 2.11%, and 1.54% of students respectively indicated "very dissatisfied" opinions about the teaching of these three types of knowledge. These findings underscore the efficacy of the university's engineering

Table 1: Thirty six types of knowledge, skills and competencies

10 Types of knowledge	13 Skills	13 Abilities
Basic knowledge of mathematics, physics, chemistry and engineering sciences	Apply engineering science knowledge to practice	Self-driven and motivated
Knowledge of systems integration	Identify processing and solving engineering problems	Curiosity and a desire to keep learning
Knowledge of ethics, integrity, and scientific and technological responsibility	Prioritize and manage time effectively	Ability to innovate
Information technology knowledge	Critical thinking	Creativity
Network security knowledge	Data skills	Flexibility and the ability to adapt to rapid change
Knowledge related to design	Use of new technologies, skills, and modern engineering tools	Teamwork and the ability to work in multidisciplinary teams
Knowledge of conflict resolution	Systems thinking	Good personal and professional judgment
Public safety knowledge	Effective communication	The ability to deal with ambiguity and complexity
Extensive cultural knowledge	Application based research and evaluation	Technical intuition and metacognitive skills
Economic and business knowledge	Create vision and plan for the future	Entrepreneurship and entrepreneurial ability
	Project management	Risk-taking
	Coaching skills	Ownership and the ability to take charge
	Leadership	Emotional Intelligence

Table 2: Profile of Sample Students

Item		Number of students	Scale
Gender	Male	1968	80.0
	Female	492	20.0
Grade	Freshman year	905	36.8
	Sophomore year	626	25.4
	Junior year	346	14.1
	Senior	583	23.7
Major categories	Marine engineering classes	673	27.4
	Aerospace	405	16.5
	Energy and power	352	14.3
	Information	349	14.2
	Materials and chemicals	273	11.1
	Intelligent manufacturing	229	9.3
	Mechanics	160	6.5
	Other	19	0.7
Performance rankings	Top 20%	418	17.0
	21% - 50%	547	22.2
	51% - 75%	420	17.1
	Last 25%	170	6.9
	Freshman year not yet ranked	905	36.8

programs in addressing the primary knowledge requirements of students and in delivering high-quality teaching in these core knowledge domains, thereby garnering acknowledgment and commendation from the student body.

Evaluation of 13 skills by Chinese engineering undergraduates

Upon examining the mean values of the thirteen skills, it is discernible that students regard the following three skills as paramount for engineering majors: the application of engineering science knowledge to practical scenarios, the identification and resolution of engineering problems, and effective prioritization and time management. Notably, the first two skills are also ranked as the top two in terms of teaching quality within their academic programs, albeit in a revered order (Table 4). Conversely, the students' satisfaction with effective prioritization and time management skills is relatively lower, with 1.66% expressing "dissatisfaction"

Table 3: Students' evaluation of 10 kinds of knowledge

	For engineering majors Significance		The transfer of knowledge in the field of study	
	M	**SD**	**M**	**SD**
Basic knowledge of mathematics, physics, chemistry and engineering sciences	5.46	0.91	3.43	0.65
Knowledge of systems integration	5.28	0.95	3.23	0.72
Knowledge of ethics, integrity, and technical responsibility	5.27	1.03	3.30	0.71
Knowledge of Information Technology	5.18	0.96	3.20	0.73
Cybersecurity knowledge	5.04	1.05	3.13	0.77
Design-related knowledge	4.86	1.13	3.05	0.81
Conflict resolution knowledge	4.77	1.67	2.99	0.83
Knowledge of public safety	4.74	1.20	3.03	0.82
Extensive cultural knowledge	4.26	1.30	2.92	0.84
Economic and business knowledge	3.98	1.34	2.69	0.92

Table 4: Students' evaluation of 13 skills

	Evaluation of the importance of the engineering profession		How the major imparts skills	
	M	**SD**	**M**	**SD**
Application of engineering science knowledge to practice	5.48	0.82	3.32	0.68
Identify approaches to and solutions to engineering problems	5.47	0.83	3.33	0.65
Prioritize and time manage effectively	5.40	0.87	3.22	0.72
Critical thinking	5.39	0.86	3.28	0.69
Data skills	5.38	0.84	3.29	0.69
Use new technologies, skills, and modern engineering tools	5.37	0.86	3.31	0.68
Systems thinking	5.35	0.85	3.27	0.68
Effective communication	5.34	0.87	3.20	0.73
Application based research and evaluation	5.32	0.88	3.28	0.68
Create vision and plan for the future	5.23	0.93	3.22	0.72
Project Management	5.23	0.91	3.17	0.75
Mentoring skills	5.14	0.96	3.24	0.70
Leadership	4.99	1.02	3.06	0.81

or "strong dissatisfaction." This places the skill of effective prioritization and time management fourth from the bottom in terms of teaching satisfaction across all assessed abilities.

Evaluation of 13 abilities by Chinese engineering undergraduates

Based on the mean values of the thirteen abilities, students identified the three most critical abilities for achieving success in engineering as self-motivation and drive, curiosity coupled with a desire for lifelong learning, and innovative thinking. Specifically, 65.12%, 64.02%, and 61.38% of students, respectively, deemed these three abilities as "very important" for their success in engineering majors. Notably, curiosity and the desire for continuous learning, along with self-drive and motivation, also ranked first and third in the evaluation of students' professional teaching satisfaction (Table 5). Conversely, students' satisfaction with their innovation ability was relatively low, with only 40.93% of students expressing "very satisfied" with it, placing it sixth among all assessed abilities.

Analysis of differences in evaluation of core competence of Chinese and American engineering undergraduates

Differences in the evaluation of 10 kinds of knowledge by Chinese and American engineering undergraduates

For Chinese students, there exists a positive correlation between the importance attributed to knowledge and the perceived teaching quality. The three knowledge

Table 5: Students' evaluation of the 13 abilities

	Evaluation of the importance of the engineering profession		How the major imparts the ability	
	M	SD	M	SD
Self-drive and motivation	5.48	0.83	3.31	0.69
Curiosity and a desire to keep learning	5.47	0.83	3.33	0.67
Ability to innovate	5.43	0.84	3.29	0.68
Creativity	5.42	0.84	3.29	0.70
Flexibility and the ability to adapt to rapid change	5.41	0.84	3.30	0.68
The ability to work in a team and in a multidisciplinary team	5.39	0.87	3.32	0.70
Good personal and professional judgment	5.39	0.86	3.30	0.67
Ability to deal with ambiguity and complexity	5.37	0.86	3.29	0.68
Technical intuition and metacognitive ability	5.36	0.86	3.28	0.69
Entrepreneurship and entrepreneurial ability	5.27	0.95	3.26	0.71
Ability to take risks	5.22	0.92	3.21	0.75
The ability to own and take charge	5.21	0.93	3.24	0.72
Emotional Intelligence	5.12	1.02	3.12	0.80

domains deemed most critical for engineering majors also correspond to those with the highest teaching quality, while economic and business knowledge are considered the least significant (Table 6), with correspondingly the poorest teaching quality. This finding underscores that students are inclined to allocate more time and effort to tasks they deem important.

In contrast, American students ranked the quality of basic teaching second but did not consider it as important for engineering (Table 7). This diverges from the perspective of Chinese students, who identified basic knowledge as the most important, with the highest teaching quality. The underlying reason is that engineering education in both China and the United States has established a robust knowledge foundation for students, effectively meeting their knowledge requirements. Additionally, it reflects that American students make a clear distinction between engineering, science, and technology. In their view, design knowledge supersedes basic knowledge in importance for engineering majors. Furthermore, American students regard information technology knowledge as the least important for engineering majors, with the worst teaching quality. This observation is particularly noteworthy. In the era of Industry 4.0, where physical and digital spaces are converging,[17] the application of information technology is becoming increasingly pervasive and crucial. Students are expected to possess sufficient information technology knowledge to meet the demands of this new era. However, American students' belief that information technology knowledge is the least important for engineering majors may stem from their perception of engineering as a design discipline rather than a technological one. It may also be due to the United States' longstanding leadership in information technology, where students have already integrated information technology into every facet of daily life and learning, thus not considering it as significant.

Differences in evaluation of 13 skills among Chinese and American engineering undergraduates

Both Chinese and American students place a high premium on the skills of identifying, handling, and solving engineering problems (Table 8), thereby affirming the fundamental purpose of engineering as a discipline aimed at transforming nature and advancing practical applications. American students, in particular, place significant emphasis on effective communication and leadership, deeming the teaching quality of these two skills to be of paramount importance (Table 9). These "soft skills" are instrumental in enhancing team cooperation and efficiency, as well as in augmenting individual influence within teams, which are quintessential competencies for leadership roles. The leadership education in American universities is recognized as being at the forefront globally.[18] Students' positive evaluations of the importance and educational quality of these skills suggest a keen aspiration among American students to assume leadership positions.

Conversely, Chinese students perceive effective communication and leadership as less critical for engineering majors, instead prioritizing the practical application of engineering science knowledge. This hands-on problem-solving capability underscores the notion that "engineering is an activity intensive in technological innovation, and the primary objective of engineering education is to cultivate technologically innovative talents".[19] In essence, Chinese students focus

Table 6: Chinese and American engineering undergraduates' evaluation of the importance of 10 kinds of knowledge

Chinese engineering undergraduates		American engineering undergraduates	
Types of knowledge	**Percentage (%)**	**Type of knowledge**	**Percentage (%)**
The three most important kinds of knowledge for engineering majors			
The basics	67	Knowledge of ethical integrity and scientific and technological responsibility	99
Knowledge of moral integrity and scientific and technological responsibility	58	Design-related knowledge	97
Knowledge of systems integration	54	Knowledge of public safety	96
The least important kind of knowledge for the engineering profession			
Economic and business knowledge	17	Information technology knowledge	67

Table 7: Evaluation of 10 kinds of knowledge education quality of Chinese and American engineering undergraduates

Chinese engineering undergraduates		American engineering undergraduates	
Types of knowledge	**Percentage (%)**	**Type of knowledge**	**Percentage (%)**
Three kinds of knowledge with the best teaching quality			
The basics	50	Knowledge of ethical integrity and scientific and technological responsibility	46
Knowledge of systems integration	38	Basics	46
Knowledge of ethical integrity and scientific and technological responsibility	43	Design-related knowledge	38
The kind of knowledge with the worst teaching quality			
Economic and business knowledge	22	Information technology knowledge	5

Table 8: Evaluation of the importance of 13 kinds of skills by Chinese and American engineering undergraduates

Chinese engineering undergraduates		American engineering undergraduates	
Skill type	**Percentage (%)**	**Skill type**	**Percentage (%)**
The three most important skills for engineering majors			
Apply engineering science knowledge to Practice	65	Communicate effectively	100
Identify, deal with and solve engineering problems	64	Identify, process and solve engineering problems	99
Prioritize and time manage effectively	60	Leadership	98
The least important skill for the engineering profession			
Skill type	Percentage (%)	Skill type	Percentage (%)
leadership	40	Systems thinking	78

more intently on mastering and applying foundational knowledge, dedicating a significant amount of time to coursework and scientific research competitions. Their future aspirations lean towards becoming practitioners who drive the advancement of engineering practices.

This divergence in priorities reflects underlying cultural differences. The leadership culture in the United States is rooted in Western cultural traditions, particularly the Puritan work ethic and the values of individualism, which emphasize personal achievements and self-actualization. American students are motivated to showcase their talents in leadership roles to attain personal glory and recognition. In contrast, the ethos of getting things done in China is deeply embedded in traditional Chinese culture. Confucianism, a cornerstone of traditional Chinese values, underscores the social roles and responsibilities of individuals and promotes the philosophy of "cultivating oneself, regulating the family, governing the state, and bringing peace to the world." The motivation for Chinese students often stems from a sense of duty towards society, family, and the collective. Moreover, the collectivist perspective inherent in Chinese culture is highly pronounced. Chinese students believe that an individual's capabilities are finite and that only through integration into a collective can one maximize their

Table 9: Evaluation of the education quality of 13 skills among Chinese and American engineering undergraduates

Chinese engineering undergraduates		American engineering undergraduates	
Skill type	**Percentage (%)**	**Skill type**	**Percentage (%)**
The three skills with the best teaching quality			
Apply engineering science knowledge to practice	43	Identify approaches to and solutions to engineering problems	48
Identify, process and solve engineering problems	42	Leadership	47
Use new technologies, skills, and modern engineering tools	41	Communicate effectively	44
One of the worst skills in teaching quality			
Skill type	Percentage (%)	Skill type	Percentage (%)
Leadership	33	Create vision and plan for the future	17

impact, thereby reinforcing the pragmatic approach to achieving tangible results.

Differences in the evaluation of 13 abilities by Chinese and American engineering undergraduates

Chinese students place the highest value on the ability to be self-driven and motivated, while their American counterparts prioritize teamwork and the capacity to collaborate within multidisciplinary teams (Table 10). This dichotomy suggests that Chinese students emphasize internal motivation and individual effort, whereas American students focus more on external cooperation and problem-solving through teamwork. This perspective also elucidates why American students place a high premium on effective communication and leadership skills, which align with their aspirations for leadership roles. Concurrently, American students assign the least importance to entrepreneurship, albeit considering its teaching quality to be moderate. Despite the United States' robust culture of innovation and entrepreneurship, where entrepreneurship education is widely prevalent at a large scale,[20] with universities offering relevant courses, students do not perceive entrepreneurial ability as a core factor for their immediate development.

Furthermore, Chinese students rate emotional intelligence as the least important and its teaching quality as the poorest (Table 11). This perception is largely attributable to the long-standing emphasis in China's talent training on knowledge acquisition and assessment. Traditional exam-oriented education tends to prioritize intelligence quotient (IQ) over emotional quotient (EQ), focusing on scores rather than holistic abilities.[21] Consequently, the study of specialized and foundational courses consumes the majority of undergraduates' time. In comparison, colleges and universities devote insufficient attention to the development of psychological qualities such as emotional intelligence, with a corresponding lack of curriculum depth in this area. Additionally, within the realm of family education, parents place significantly less emphasis on nurturing emotional intelligence compared to knowledge learning, further diminishing the perceived importance of emotional intelligence among students.

CONCLUSIONS AND SUGGESTIONS

Research conclusions

The survey findings indicate that future outstanding engineers are anticipated to embody a dual proficiency in both deep domain knowledge and a broad spectrum of professional skills, thereby emerging as "T-shaped professionals"(Figure 1). The cultivation of such T-shaped professionals, who are adept in specialized skills while also possessing comprehensive domain knowledge, necessitates a multifaceted educational approach. Students should be equipped with a foundational knowledge in science and mathematics, complemented by an understanding of the social sciences, humanities, and arts. Additionally, there should be a pronounced emphasis on entrepreneurship, design, and leadership. Furthermore, students are expected to undergo rigorous training in one or more engineering disciplines to fully realize their potential as well-rounded professionals.

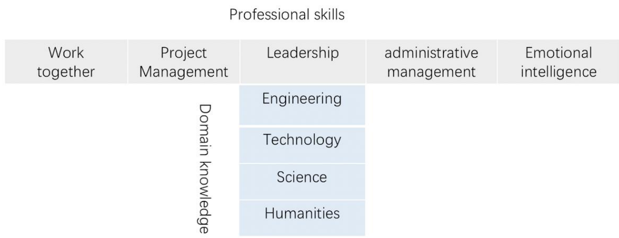

Figure 1. Model of the T-shaped professional.

Suggestions

Optimizing curriculum design and reaching methods

In terms of knowledge: It is imperative to enhance the

Table 10: Evaluation on the importance of 13 abilities of Chinese and American engineering undergraduates

Chinese engineering undergraduates		American engineering undergraduates	
Capability type	**Percentage (%)**	**Type of ability**	**Percentage (%)**
The three most important abilities for engineering majors			
Self-driven and motivated	65	Ability to collaborate and work in a multidisciplinary team	99
Curiosity and a desire to keep learning	64	Good personal and professional judgment	99
Ability to innovate	61	Self-drive and motivation	98
One of the least important skills for engineering majors			
Type of ability	Percentage (%)	Type of ability	Percentage (%)
Eq (Emotional Intelligence)	46	Entrepreneurial ability	61

Table 11: Evaluation of the education quality of 13 abilities among Chinese and American engineering undergraduates

Chinese engineering undergraduates		American engineering undergraduates	
Type of ability	**Percentage (%)**	**Type of ability**	**Percentage (%)**
The three abilities with the best teaching quality			
Teamwork and the ability to work in multidisciplinary teams	43	The ability to take ownership and responsibility	43
Self-drive and motivation	42	Good personal and professional judgment	41
Curiosity and a desire to continue learning	41	Curiosity and a desire to keep learning	39
The ability to teach at its worst			
Eq (Emotional Intelligence)	35	Ability to take risks	12

depth and breadth of foundational knowledge instruction. Recognizing the high value students place on basic knowledge in mathematics, physics, chemistry, and engineering sciences, curriculum design should expand modules to include cutting-edge knowledge in these fundamental disciplines. The introduction of the latest scientific research achievements can broaden students' horizons. For system integration knowledge, the development of project-based practical courses is essential, allowing students to engage in the entire process from system design, construction to integration testing in real projects, thereby deepening their understanding and application abilities. Regarding ethical integrity and scientific and technological responsibility, in addition to theoretical teaching, the introduction of real-case discussions is crucial. Analyzing real-world events such as academic misconduct and scientific and technological ethics issues can guide students to think deeply and cultivate correct values.

In terms of skills: There is a need to intensify practical skills training and avoid the tendency towards "engineering science".[22] Given students' emphasis on skills such as applying engineering science knowledge to practice and identifying and solving engineering problems, establishing more internship bases in collaboration with enterprises is essential. This provides students with long-term and stable practical opportunities, enhancing their ability to solve real-world problems. While acquiring practical skills and experience, students can also improve their problem-solving, teamwork, and innovation abilities.[23] Moreover, improving the cultivation of time management and priority-setting skills is necessary. Considering the relatively low satisfaction of students with effective priority-setting and time-management skills, offering specialized courses in time management and project management is recommended. Through methods such as theoretical explanation, case analysis, and simulation projects, students can learn scientific time-management methods and task-priority-determination techniques. Encouraging students to apply these learned methods to create detailed study and work plans will gradually improve their skills in this area.

In terms of abilities: On one hand, stimulating the cultivation of innovation ability is crucial. In light of students' emphasis on innovative thinking but relatively low satisfaction, establishing an innovation credit system to encourage participation in scientific research projects, innovation and entrepreneurship competitions, and other activities for corresponding credits is beneficial. Additionally, offering courses on innovation methods and thinking training, teaching students innovation techniques such as brainstorming and the theory of inventive problem solving (TRIZ), and cultivating innovative thinking habits is essential. On the other hand, enhancing the cultivation of curiosity and the desire for lifelong learning is important. Creating a strong academic atmosphere, regularly holding academic forums, lectures, and other activities, and inviting well-known scholars from home and abroad to share cutting-edge research results and scientific research experiences can stimulate students' curiosity and thirst for knowledge.

Cultivating cross - cultural competence and an international perspective

On the one hand, learn from American educational experiences: It is essential to focus on the integration of design knowledge and information technology knowledge. Considering American students' attitudes towards information technology and the demands of the Industry 4.0 era, there should be an enhanced application of information technology in engineering education. Courses such as the application of artificial intelligence in engineering, big data and engineering decision-making should be offered, enabling students to master the cutting-edge applications of information technology in the engineering field and improve their digital literacy. Additionally, communication and leadership skills should be cultivated. Drawing from the experiences of American universities in student leadership education, leadership training courses and practical projects should be conducted through organizing team activities and simulating leadership scenarios. Based on situational learning, communication-strengthening curriculum tasks should be jointly designed and evaluated, adopting a multi-modal framework that includes academic, workplace, and social backgrounds, and conducting effective communication skills teaching to cultivate students' communication abilities.[24]

On the other hand, inherit the advantages of Chinese culture: The cultivation of practical and collective cooperation spirit should be strengthened. Continuing to emphasize the characteristic attention to practice among Chinese students, deepening school-enterprise cooperation, and carrying out industry-education-research integration projects will enable students to continuously improve their practical abilities in actual engineering projects, becoming doers who promote the progress of engineering practice. The cultivation of a sense of responsibility and internal driving force should also be deepened. Based on the traditional Chinese cultural emphasis on personal social roles and responsibilities, social responsibility education should be integrated into educational and teaching practices, guiding students to establish correct values and professional outlooks, thereby stimulating their internal driving force and sense of responsibility. Students can be encouraged to participate in social practice and public welfare projects, such as community infrastructure construction and environmental protection projects, enabling them to enhance their sense of social responsibility through practice and closely align personal development with social needs.

Attaching importance to emotional intelligence cultivation and personalized development

Firstly, enhance the cultivation of emotional intelligence: It is crucial to refine the curriculum system dedicated to emotional intelligence development. Considering the relatively low importance and teaching quality evaluations attributed to emotional intelligence by Chinese students, universities should take proactive steps to improve this curriculum system. Specialized courses, such as emotion management and interpersonal communication psychology, should be offered to teach students essential emotional intelligence skills, including emotion recognition, regulation, and effective communication. Furthermore, the integration of emotional intelligence cultivation into other professional courses and practical activities is necessary. For instance, within team projects, students should be guided to understand the emotions of others and coordinate relationships among team members, thereby enhancing their practical application of emotional intelligence.

Secondly, pay heed to individual differences among students: Educators, including teachers, counselors, and class advisors, must collaboratively focus on the individual differences among students. Through regular student interviews and psychological assessments, it is important to gain insights into students' interests, strengths, and potential. Based on these individual characteristics, personalized learning and development suggestions should be provided. This includes assisting students in formulating learning plans and career development plans that align with their unique needs, such as guiding them in selecting appropriate elective courses, engaging in specific scientific research projects, or participating in club activities that match their interests and aspirations.

Lastly, provide diverse development platforms for students: Establishing a variety of development platforms, such as innovation and entrepreneurship clubs, academic societies, and art groups, is essential to cater to the diverse interests of students. Students should have the opportunity to choose and participate in activities that resonate with their interests and specializations, allowing them to leverage their personal strengths and achieve personalized development. Additionally, setting up scholarships for personalized development will reward outstanding performance in various fields, encourage in-depth development in areas of expertise, and nurture engineering talents with distinctive advantages.

DECLARATIONS

Author contributions

Liu Y: Conceptualization, Methodology, Resources, Writing—Original draft, Project administration, and Funding acquisition. Xiao YT: Data curation, Writing—Review and Editing, Visualization, communication with the editor and article revision. He XM: Questionnaire design, distribution, collection, and Data analysis. All authors have read and approved the final version.

Ethics approval

Not applicable.

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Conflict of interest

The author has no conflicts of interest to declare.

Data availability statement

No additional data.

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