

Original article

High willingness, weak cognition: The global competence paradox of emerging engineering undergraduates

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Abstract:

To address the demand for high-quality engineering talents amid globalization and technological transformation, and enhance the international competitiveness of emerging engineering talents, this study constructs an evaluation system covering four dimensions—knowledge and understanding, skill, attitudes and values, action and willingness—based on PISA global competence framework. A survey was conducted among 800 undergraduates from 20 universities with emerging engineering disciplines in China. The study finds that these universities presents a structural imbalance characterized by “positive attitudes with weak cognition” with obvious deficiencies in knowledge comprehension and cross-cultural skill; students’ global competence is significantly influenced by factors such as gender, academic background, maternal education level, and international exchange experience; science and engineering students are significantly inferior to liberal arts students in terms of global knowledge and problem awareness. Accordingly, three improvement paths are proposed. First, reconstruct the curriculum system to bridge the structural gap between cognition and competence. Second, optimize the mobility mechanism to enhance the educational effectiveness of international exchanges. Third, promote interdisciplinary integration to break through the limitations of humanistic vision among science and engineering students.

1. Introduction

In 2017, the Construction of Emerging Engineering Disciplines (CEED) was launched by the Ministry of Education of China, which is an engineering education reform initiative. It aims to respond to the new round of technological revolution and industrial transformation, serve the national strategic needs, and cultivate future-oriented engineering and technological talents with interdisciplinary integration capabilities. Based on the Excellent Engineer Education and Training Program, this initiative emphasizes the shift from discipline-oriented to industry demand-oriented development. By transforming traditional engineering majors, laying out emerging fields, and innovating talent training models, it strives to build an engineering education system that adapts to the development of the new economy.

In the context of global integration and economic global-

ization, it is particularly critical for universities with emerging engineering disciplines to cultivate students with global competence. This trend is not only an inevitable direction for the development of higher education but also a vital manifestation of national strategic needs (Qiao & Lu, 2022). On one hand, technology and industry are globalizing. Modern technological and industrial development is no longer confined to single nations, as multinational corporations and international cooperation projects continue to expand in scale. Students in emerging engineering disciplines can only adapt to this trend by possessing robust global competence. On the other hand, many engineering problems exhibit global characteristics that require globally competent talents to resolve. To better respond to these realities, China has introduced significant policies, such as the “Belt and Road” initiative and the manufacturing power strategy, which require engineering and technical personnel to possess international perspectives to promote domestic and

international cooperation (Shao, 2020).

In the current context, the training of globally competent talents in Chinese new engineering universities aims to enable them to face various complex problems and demonstrate outstanding innovation capabilities in the context of globalization. However, there may currently be a lack of common understanding of globally competent talents in new engineering universities, a lack of specialized systems for cultivating such talents, and a serious disconnect between the training objectives, students' subjective imagination of related professions, and the employment standards and actual needs of employers. In addition, China is understaffed in many international organizations of the United Nations system and is faced with the dilemma of being unable to dispatch international staff to organizations like UNESCO. One of the reasons is that there is a split between foreign language and professional discipline education in China's talent cultivation at present, which leads to the so-called "problem that those who can speak foreign languages do not have majors, and those who know majors cannot speak foreign languages" (Liu, 2023).

These dilemmas highlight the urgency of systematically evaluating and reforming the global competence training system for emerging engineering talents. To address this, this study aims to answer the following three core questions through empirical investigation: What is the global competence level of undergraduates in new engineering universities? What are the specific problems and structural shortcomings in the dimensions of knowledge, skill, attitudes, and actions? How should an effective training path be constructed to systematically improve their global competence?

Existing research mostly focuses on macro-theoretical discussions or case studies of single universities, and systematic empirical research on the specific group of new engineering undergraduates is still weak. In terms of influencing factors, most studies focus on the meso-level such as schools and courses, while the mechanism of micro-environmental variables such as family cultural capital and parents' education level is insufficiently discussed. This study aims to fill the above research gaps, systematically investigate new engineering undergraduates as an independent group, and incorporate micro-variables such as family background into the analysis framework to build a more comprehensive "individual-family-school" multi-level influence factor model.

2. Literature review

2.1 The connotation of global competence

In the early to mid-20th century, following two world wars, the demand for international cooperation and global governance gave rise to the initial formation of global consciousness. The establishment of the United Nations and the rise of various international organizations marked early attempts at global cooperation and problem-solving. Subsequently, in the 1960s and 1970s, global education emerged as a new educational model emphasizing the cultivation of students' awareness of global issues and international understanding. During this period, with the development of information

technology and the deepening of economic globalization, international educational exchanges became more frequent. Studying abroad, international cooperation projects, and distance education became the norm, providing more practical opportunities for cultivating global competence. The term "Global Competence" first appeared in the Western context in the 1990s. In 1993, Richard D. Lambert, the father of "global competence" education, first attempted to define the concept from an educational perspective. He identified five elements that distinguish global competence: knowledge, empathy, approval, foreign language competence, and task performance.

Entering the 21st century, global competence began to be widely discussed as a distinct concept. Dearthoff (2006) emphasized that intercultural competence involves not only knowledge acquisition but also attitudes such as openness, respect, and adaptability, highlighting the developmental and process-oriented nature of global competence. Educators and policy makers started to realize that students need global competence to succeed in globalization. In 2009, Reimers proposed three dimensions of global competence: a positive attitude towards cultural differences, language proficiency, and a deep understanding of and critical thinking skill regarding global topics and globalization processes (Reimers (2009)). In 2011, the Council of Chief State School Officers and the Asia Society jointly proposed a new interpretation, stating that individuals should have the ability to understand global issues and take corresponding actions to address them properly (Boix Mansilla & Jackson, 2011). Boix Mansilla & Jackson (2011) further emphasized that global competence is a vital component of education, defining it as the ability and disposition to understand and act on issues of global significance. In 2018, the Organization for Economic Cooperation and Development (OECD) released the PISA Global Competence Framework, further clarifying the definition and making it an important dimension for assessing the abilities of international students. This framework defines global competence as the ability to examine local, global, and intercultural issues, to understand and appreciate the perspectives and worldviews of others, to engage in open, appropriate, and effective interactions with people from different cultures, and to act for collective well-being and sustainable development (OECD, 2018). More recent research in engineering education has further stressed that global competence should be systematically integrated into technical curricula to prepare students for diverse and interconnected global workplaces (Richter, 2025).

Based on the literature above, this study defines the global competence of students in universities with emerging engineering disciplines as the ability to possess interdisciplinary knowledge, cross-cultural communication skill, innovative thinking, and a global perspective within the context of globalization. They must be able to effectively tackle complex problems, participate in international cooperation, and promote sustainable development in international engineering and technology fields.

2.2 Current status of research on global competence

In recent years, global competence has gradually become a core issue in educational research, with many domestic scholars conducting in-depth studies. In 2017, Tsinghua University defined global competence as the ability to learn, work, and communicate effectively in an international multicultural environment, constructing a core competency model that includes six dimensions: language, global awareness, self-awareness, ethics and morality, open attitude, and communication and collaboration (Tsinghua University, 2017). Subsequently, Teng et al. (2018) analyzed three developmental logics of global competence education: module element logic, subject-object relationship logic, and action program logic. These three logics not only enrich the theoretical connotation but also promote the transformation of global competence education concepts into practice. In the same year, Teng et al. (2018) reviewed the OECD's PISA Global Competence Framework, clarifying four key dimensions: examining local and global issues, respecting diverse perspectives, effective cross-cultural interaction, and taking responsible action for sustainable development. Sun (2021) further emphasized that China should be guided by the concept of "a community with a shared future for mankind" to construct and improve the theoretical system of global competence education, promoting implementation through policy guidance, service learning, and online education.

However, existing research has mostly focused on macro-level theoretical discussions or case studies of individual universities, while systematic empirical research specifically targeting undergraduates in emerging engineering disciplines remains insufficient. In exploring influencing factors, studies have predominantly concentrated on the meso-level of schools and curricula, with insufficient examination of the mechanisms of micro-level environmental variables such as family cultural capital and parental education levels. This study aims to address these research gaps by treating undergraduates in emerging engineering disciplines as a distinct group for systematic empirical investigation and by conducting an in-depth analysis of the structural characteristics and group-specific features of their global competence. Furthermore, moving beyond a singular focus on school education, it incorporates micro-level variables such as family background (e.g., parental education level) into the analytical framework, with the goal of constructing a more comprehensive multi-level "individual-family-school" model of influencing factors and revealing the complex underlying mechanisms in the formation of global competence among emerging engineering talent.

2.3 The connotative elements of global competence for undergraduates in universities with emerging engineering disciplines

In this study, "undergraduates in universities with emerging engineering disciplines" refers to all undergraduate students receiving education in universities established under the emerging engineering initiative, encompassing students

from diverse academic backgrounds such as engineering, science, and humanities. To align with the interdisciplinary and integrated educational ecology of these universities and to respond to the broad demand for composite talents in globalization, this study constructs the connotative elements of global competence by taking into account both the common foundational literacies shared by all students and the distinctive orientation of emerging engineering education.

Combining the professional characteristics of China's emerging engineering education with student characteristics, and drawing on the global competence framework in the PISA 2018 test, the "Research Questionnaire on the Cultivation of Global Competence of Engineering Undergraduates in the Context of Emerging Engineering" (Li, 2022), the "Research Questionnaire on the Cultivation of Global Competence of Normal Students in the Era of Internet Plus Education" (Zhang, 2021), the "Questionnaire on the Development of International Competence of College Graduates" (Liu & Wu, 2015), and relevant policy requirements (Ministry of Education of the People's Republic of China, 2021, 2023; The Central Committee of the Communist Party of China & the State Council, 2016), the connotative elements of global competence for students in universities with emerging engineering disciplines have been constructed. These cover four core dimensions: knowledge and understanding, skill, attitudes and values, and action and willingness. All dimensions are interconnected, coordinated, and mutually supportive, jointly shaping a comprehensive engineering talent literacy architecture that meets the needs of global development.

The knowledge and understanding dimension focuses on global engineering issues and awareness of cross-cultural engineering norms; the skill dimension emphasizes multilingual engineering communication, adaptation to international standards, and collaboration in diverse teams; the attitudes and values dimension highlights technical ethics, awareness of a community with a shared future for mankind, and cultural inclusivity; and the action and willingness dimension concerns the initiative and practical application ability to engage in international engineering practices and solve global problems. The cultivation of global competence in universities with emerging engineering disciplines should be founded on knowledge, applied through skill, oriented by values, and result in action, ultimately shaping interdisciplinary talents who possess both technical expertise and a global perspective, thereby contributing to the sustainable development goals of human society.

3. Research methods

This study uses a questionnaire survey method to gain a deeper understanding of the current status of global competence among students in new engineering universities.

3.1 Questionnaire design

Based on the connotative elements framework constructed for this study, a "Global Competence Questionnaire for Undergraduates in Universities with Emerging Engineering Disciplines" was developed to extract four primary dimensions

and nine secondary factors (Table 1). The questionnaire consists of two main parts: background information and global competence status. Background information includes 9 items covering personal basic information, overseas experience, etc.; Global Competence Status includes 31 items covering understanding of global issues, cross-cultural knowledge, critical thinking, cross-cultural communication skill, adaptability and problem-solving abilities, global awareness, respect for diversity, and more. The scale adopts a Likert 5-point scoring method, where 5 indicates “completely consistent” and 1 indicates “completely inconsistent”.

Table 1. Global competence dimensions and factors of undergraduates in universities with emerging engineering disciplines.

Dimension	Factor
Knowledge and understanding	World knowledge
	Global understanding
Skill	Using tools
	Cross-cultural communication
Attitudes and values	Internationalization awareness
	Internationalization attitude
	Value recognition
Action and willingness	Willingness to solve global problems
	Actions taken to address global issues

3.2 Survey implementation and data collection

To ensure the representativeness and scientific rigor of the research, the survey adopted a stratified sampling strategy. First, following the principle of “combining typicality with regional balance,” universities participating in the second batch of Emerging Engineering research and practice projects announced by the Ministry of Education were selected as the primary sampling sources (Table 2). The survey process was carried out in two stages: The first stage was a pilot survey, distributing 150 questionnaires to test reliability and validity, clarity of questions, and rationality of options, after which the questionnaire was optimized based on feedback. The second stage was the formal survey, distributing a total of 800 questionnaires. After data screening and cleaning, 703 valid questionnaires were retained. Valid responses were mainly collected from 14 target universities, including Jiangnan University, Jilin University, Southeast University, Zhejiang University, China Agricultural University, and Tianjin University. A small number of responses were also obtained from several non-target institutions. The sample consisted of 353 males (50.2%) and 350 females (49.8%); 544 students were from science and engineering majors (77.4%) and 159 from liberal arts majors (22.6%). The effective response rate was 87.9%. The data obtained comprehensively reflects the sample’s performance in dimensions such as cross-cultural communication, international vision, and global knowledge, providing a solid

foundation for subsequent quantitative analysis.

Table 2. Universities included in the second batch of “emerging engineering” research and practice projects.

Serialn number	Province	School name	Number of universities
1	Beijing	Beijing Institute of Technology, China Agricultural University, Tsinghua University, Beijing Jiaotong University, Beihang University	5
2	Shaanxi Province	Xi’an Jiaotong University, Xidian University, Chang’an University	3
3	Shanghai	Tongji University, Fudan University	2
4	Jiangsu Province	Southeast University, Jiangnan University	2
5	Tianjin	Tianjin University	1
6	Heilongjiang Province	Harbin Institute of Technology	1
7	Liaoning Province	Dalian University of Technology	1
8	Zhejiang Province	Zhejiang University	1
9	Sichuan Province	Sichuan University	1
10	Jilin Province	Jilin University	1
11	Shandong Province	Shandong University	1
12	Hubei Province	Huazhong University of Science and Technology	1

Data Source: notice of the general office of the Ministry of Education on the announcement of the second batch of emerging engineering research and practice projects.

3.3 Quantitative analysis methods

The study uses SPSS statistical software to process and analyze the questionnaire data. Specific methods include:

•**Descriptive statistics:** Used to characterize the sample and calculate the mean and standard deviation of global competence dimension scores to visually present their overall level and internal structure.

•**Correlation analysis:** Pearson correlation coefficients were calculated to test the internal correlation between the four primary dimensions and nine secondary factors, preliminarily exploring the coupling characteristics of the capability structure.

•**Multiple linear regression analysis:** Controlling for other variables, regression models were constructed with the total global competence score and dimension scores as dependent variables. The study systematically examined the

independent effects of variables such as personal characteristics (gender, discipline, etc.), family background (parents' education level), and international exchange experience to identify key influencing factors.

Based on the literature review and research framework, this paper proposes the following verifiable research hypotheses:

●**H1:** The development of various dimensions of global competence in undergraduates of universities with emerging engineering disciplines is unbalanced, with potential shortcomings in some dimensions.

●**H2:** Personal characteristics of emerging engineering undergraduates (such as gender, disciplinary background) have a significant impact on their global competence.

●**H3:** Students' international exchange experience is positively correlated with global competence, with short-term (1-6 months) international exchange experience having a stronger predictive effect.

4. Data analysis

4.1 Reliability and validity analysis

The Cronbach's alpha coefficients for all four dimensions are higher than 0.8, with a minimum of 0.818, and the overall Cronbach's alpha for the scale is 0.94 (Table 3). This indicates that the reliability and data quality of this study are good, and the research data is authentic and reliable. Validity is ensured through content validity and construct validity. For content validity, the instrument was developed based on established scales from domestic and international literature, and the items were rigorously reviewed by three experts in higher education research to ensure clarity and relevance. Construct validity was secured by aligning the item structure with the validated Global Competence Model for College Students (Liu & Kong, 2018; Liu et al., 2018; Liu & Wu, 2015), thereby ensuring the structural stability of the scale.

Table 3. Reliability test.

Dimension	Scale questions	Corresponding question items	Reliability
Knowledge and understanding	A11,A12,A13	8	0.855
	A21,A22,A23,A24,A25		
Skill	B11,B12	8	0.852
	B21,B22,B23,B24,B25,B26		
Attitudes and values	C11,C12,C13	10	0.846
	C21,C22,C23,C24		
	C31,C32,C33		
Action and willingness	D11,D12,D13 D21,D22	5	0.818

To further examine the construct validity of the questionnaire, this study conducted confirmatory factor analysis using Mplus 8.3. The measurement model was specified according to the established structure of four dimensions and nine indicators. The results showed that the model fit was

acceptable: $\chi^2 = 145.189$, $df = 21$, $\chi^2/df = 6.91$, CFI = 0.959, TLI = 0.930, RMSEA = 0.092, and SRMR = 0.036 (Table 4). The standardized factor loadings of the nine indicators ranged from 0.577 to 0.956, and all loadings were statistically significant, indicating that the scale had acceptable construct validity (Table 5).

Table 4. Model fit Indices of the four-factor CFA model.

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR
Four-factor CFA model	145.189	21	6.91	.959	.930	.092	.036
Recommended criteria			> .90	> .90	< .10	< .08	

Table 5. Standardized factor loadings of the confirmatory factor analysis.

Dimensions	Indicators	Standardized loading
Knowledge and understanding	World knowledge	0.748
	Global understanding	0.956
Skill	Tool use	0.577
	Cross-cultural communication	0.913
Attitudes and values	Internationalization awareness	0.740
	Internationalization attitude	0.918
	Value recognition	0.843
Action and willingness	Willingness to solve global problems	0.903
	Actions taken to address global Issues	0.733

4.2 Descriptive statistical analysis

Analysis of the mean and standard deviation of the primary dimensions reveals that the scores of undergraduates in the four dimensions of global competence are ranked as follows: attitudes and values, skill, action and willingness, and knowledge and understanding (Table 6). The attitudes and values dimension scored the highest with an average of 4.44, reflecting that students have a strong foundation in international awareness, attitudes, and value recognition. The skill dimension averaged 3.91, indicating that while students possess certain abilities in cross-cultural communication and tool usage, there is still room for improvement. The action and willingness dimension averaged 3.90, suggesting that students have motivation to participate in solving global problems, but the translation of this willingness into actual action needs strengthening. The knowledge and understanding dimension averaged 3.80, which is significantly lower, indicating that undergraduates urgently need to improve their knowledge base, particularly regarding world knowledge and globalization.

Table 6. Mean and standard deviation of each dimension.

	Mean value	Standard deviation	Variance
Knowledge and understanding	3.80	0.61	0.38
Skill	3.91	0.59	0.35
Attitudes and values	4.44	0.47	0.22
Action and willingness	3.90	0.70	0.50

Descriptive statistics (n=703)

4.3 Correlation analysis between dimensions

Correlation analysis was used to study the strength of relationships between various dimensions. Specific analysis shows a highly significant positive correlation between the four primary dimensions and nine secondary dimensions, as shown in Tables 7 and 8.

The data indicates that correlation coefficients between dimensions are generally at a medium to high level, indicating close interconnections and mutual reinforcement. Particularly noteworthy is the strong association observed between “Skill” and “Attitudes and Values” ($r = 0.679$) as well as between “Skill” and “Action and Willingness” ($r = 0.663$), reflecting the positive driving effect of competence cultivation on emotional attitudes and behavioral tendencies. Among the secondary dimensions, the correlation between “Cross-cultural Communication (S4)” and “Internationalization Awareness (S5)” is as high as 0.742, demonstrating a high degree of synergy between cross-cultural understanding and international cognitive structure. Additionally, there is a strong correlation between “Willingness to Solve Global Problems (S8)” and “Actions Taken to Address Global Issues (S9)” ($r = 0.662$), reflecting intrinsic consistency in translating willingness into action.

These statistical results empirically confirm the organic interconnections and systemic coupling among the dimensions of global competence. Knowledge and understanding serve as the cognitive foundation, providing the necessary reserve for skill development and profoundly influencing the formation of attitudes and values, thereby stimulating individuals’ willingness to engage in global affairs; conversely, the enhancement of skill not only helps deepen the understanding of knowledge but also strengthens positive attitudes and value identification; positive attitudes and values further promote proactive knowledge acquisition and conscious behavioral transformation; and the process of action and practice constitutes a feedback mechanism, continuously facilitating knowledge renewal, skill optimization, and attitude internalization. Therefore, in cultivating global competence, higher education institutions should fully recognize the synergistic effects and integrated logic among various dimensions, avoiding an isolated emphasis on any single aspect. It is essential to systematically integrate the concept of multidimensional co-education in international exchange into the curriculum design, teaching implementation, and evaluation systems of universities with emerging engineering disciplines to achieve comprehensive and coordinated

development of students’ global literacy.

4.4 Analysis of differences and regression for undergraduate global competence

4.4.1 Gender differences

T-tests were used to analyze differences in the four primary dimensions and nine secondary dimensions of global competence by gender. Gender significantly affects Skill ($t=-2.60$, $p=0.019^*$), Attitudes and Values ($t=-3.617$, $p=0.006^{**}$), World Knowledge ($t=2.006$, $p=0.037^*$), Tool Use ($t=-2.587$, $p=0.001^{**}$), Intercultural Communication ($t=-2.277$, $p=0.031^*$), Internationalization Attitude ($t=-4.461$, $p=0.000^{***}$), and Willingness to Solve Global Problems ($t=-3.752$, $p=0.010^*$). Males ($n=353$) have significantly higher levels of World Knowledge than females ($n=350$), while females score higher in Skill, Attitudes and Values, Action and Willingness, Tool Use, Intercultural Communication, Internationalization Attitude, and Willingness to Solve Global Problems. Men have an advantage in World Knowledge, possibly due to broader interests in fields such as technology and international politics, whereas women excel in skills, attitudes, and values. For example, women may find cross-cultural communication skills more natural in interpersonal and emotional contexts, and they may be more proactive and open in their international attitudes. They also demonstrate a higher willingness to solve global problems. This reflects distinct gender advantages in global competence cultivation, suggesting that universities should tailor their teaching approaches accordingly.

4.4.2 Disciplinary differences

Using independent sample t-tests, differences were analyzed between disciplines (divided into two groups: humanities-oriented majors in universities with emerging engineering disciplines, e.g., philosophy, law, education; and STEM-oriented majors, e.g., science, engineering, medicine). The discipline category significantly affected the Willingness to Solve Global Problems ($t=-4.487$, $p=0.016^*$), with the humanities group ($n=159$) showing significantly higher willingness than the STEM group ($n=544$). This reflects the emphasis on social problem analysis and humanistic care in liberal arts majors, which makes students more concerned about global issues and active in seeking solutions. It suggests that universities should strengthen the cultivation of global problem awareness and social responsibility among science and engineering students and promote disciplinary integration.

4.4.3 Grade differences

Using analysis of variance to compare the differences in the four primary and nine secondary dimensions of global competence among different grades, it was found that different grades significantly affect world knowledge ($F=2.626$, $p=0.049^*$) and tool usage ($F=4.175$, $p=0.006^{**}$). Among them, the world knowledge of junior students was significantly higher than that of other grades, while the ability to use tools increased significantly among freshmen, sophomores, juniors, and seniors. Third year students have the advantage of world knowledge or have accumulated more professional and general

Table 7. Correlation analysis of primary dimensions of global competence.

	Knowledge and understanding	Skill	Attitudes and values	Action and willingness
Knowledge and understanding				1
Skill	0.527**	1		
Attitudes and values	0.480**	0.679**	1	
Action and willingness	0.474**	0.663**	0.634**	1

Note: * represents $p < 0.05$, ** represents $p < 0.01$, *** represents $p < 0.001$

Table 8. Correlation analysis of secondary dimensions of global competence.

Dimension	S1	S2	S3	S4	S5	S6	S7	S8	S9
World knowledge ^{S1}	1								
Globalization understanding ^{S2}	0.632**	1							
Use tool ^{S3}	0.348**	0.517**	1						
Cross cultural communication ^{S4}	0.310**	0.530**	0.541**	1					
Internationalization awareness ^{S5}	0.256**	0.472**	0.409**	0.742**	1				
Internationalization attitude ^{S6}	0.156**	0.525**	0.363**	0.548**	0.606**	1			
Value recognition ^{S7}	0.203**	0.377**	0.178**	0.225**	0.239**	0.377**	1		
Willingness to solve global problems ^{S8}	0.290**	0.516**	0.415**	0.647**	0.691**	0.539**	0.273**	1	
Actions taken to address global issues ^{S9}	0.291**	0.435**	0.406**	0.540**	0.488**	0.362**	0.180**	0.662**	1

Notes: * represents $p < 0.05$, ** represents $p < 0.01$, *** represents $p < 0.001$

knowledge due to in-depth course learning. Their ability to use tools increases with grade, reflecting the importance of practical teaching and experience accumulation. Universities should plan their curriculum system reasonably and gradually improve students' internationalization ability.

4.4.4 Differences in overseas exchange experience

ANOVA was used to examine differences based on varying levels of international exchange experience. International exchange significantly affects Skill ($F=2.784$, $p=0.017^*$), Action and Willingness ($F=2.817$, $p=0.016^*$), World Knowledge ($F=2.354$, $p=0.039^*$), Tool Usage ($F=4.002$, $p=0.001^{**}$), Willingness to Solve Global Problems ($F=2.517$, $p=0.029^*$), and Actions Taken to Solve Global Problems ($F=2.449$, $p=0.033^*$). Students who engaged in exchanges for 1-12 months score significantly higher than others, with those in the 1-6 month range scoring the highest. Moderate international exchange can effectively enhance students' global competence, allowing them to experience different cultural and educational environments firsthand, broaden their horizons, and enhance their skill and willingness to take action. Recent studies have similarly shown that structured international mobility programs significantly improve students' intercultural competence, global awareness, and collaborative ability in multicultural environments (Lee et al., 2024). Knight (2004) also emphasized that internationalization should be integrated into the core functions

of higher education rather than being limited to short-term mobility itself. This suggests schools should increase support for international exchange and cooperation.

4.4.5 Global competence regression analysis

Global Competence Regression Analysis Based on the previous analysis, a regression model for the influencing factors of undergraduate global competence was constructed. The global competence mean was used as the dependent variable, with gender, major, grade, parents' education level, and overseas exchange experience as independent variables. Statistical analysis found that for the overall global competence mean, only the mother's education level was significant. Combined with the correlation analysis results (Table 8), it is necessary to further analyze the four sub-dimensions. The results (Table 9) show significant influencing factors for all four sub-dimensions: "Knowledge and Understanding," "Cross-cultural Skill," "Attitudes and Values," and "Action and Willingness".

Specifically, "Knowledge and Understanding" is significantly influenced by gender, professional category, and maternal education level; "Cross-cultural Skill" is significantly influenced by maternal education level; "Attitudes and Values" shows significant gender differences; and "Action and Willingness" is significantly influenced by maternal education level and overseas exchange experience. In the "Knowledge

Table 9. Regression analysis results of “four dimensions of global competence” (n=703).

Independent variable	Model 1 Global average competency		Model 2 Knowledge and understanding		Model 3 Cross-cultural skill		Model 4 Attitudes and values		Model 5 Action and willingness	
	Standardization coefficient	t	Standardized coefficient	t	Standardized coefficient	t	Standardized coefficient	t	Standardized coefficient	t
Constant		9.522		7.575		7.154		11.582		4.901
Gender	-0.026	-0.648	0.126***	3.099	-0.056	-1.371	-0.123**	-2.989	-0.048	-1.188
Age	-0.053	-0.728	-0.097	-1.337	-0.032	-0.438	-0.080	-1.084	0.059	0.814
Two types of majors	-0.045	-1.110	-0.081**	-2.006	-0.009	-0.223	-0.018	-0.435	-0.045	-1.093
Father's education	0.089	1.644	0.081	1.515	0.074	1.375	0.077	1.403	0.062	1.153
Mother's education	0.093*	1.687	0.113**	2.058	0.121**	2.194	-0.022	-0.388	0.108*	1.953
Grade	0.063	0.739	0.058	0.684	0.086	1.008	0.056	0.652	0.000	-0.001
CET-4	-0.010	-0.171	0.062	1.074	-0.013	-0.221	-0.050	-0.848	-0.045	-0.780
Overseas experience	0.054	1.406	0.055	1.444	0.070	1.816	-0.011	-0.276	0.075*	1.932

Notes: * represents $p < 0.05$, ** represents $p < 0.01$, *** represents $p < 0.001$. Jian & Dai (2017) pointed out that regression coefficients with significant values below 0.10 should be included.

and Understanding” dimension, controlling for other variables, a higher maternal education level correlates with a higher score. In addition, the professional category also significantly affects this dimension, with humanities students performing significantly better than STEM students. The regression results indicate that, holding other variables constant, students in the STEM group score lower on average in “Knowledge and Understanding” compared to the humanities group, reflecting that global competence knowledge among humanities students is superior to that of engineering students. For “Cross-cultural Skill,” maternal education level has a significant positive impact. Highly educated mothers typically place greater emphasis on cultivating their children’s comprehensive qualities, consciously guiding them to participate in international activities, read international publications, and learn foreign languages, thereby systematically enhancing their language abilities and cross-cultural contact. For “Attitudes and Values,” gender differences are significant, with female students scoring approximately 12.3% higher on average than males. This indicates that female students have advantages in global awareness, cultural inclusivity, and value identification. For “Action and Willingness,” both maternal education level and overseas exchange experience have significant impacts. Students with overseas exchange experience score higher in global competence action and willingness.

5. Conclusion and discussion

5.1 Basic conclusions

5.1.1 Structural imbalance indicates shortcomings

Undergraduates in universities with emerging engineering disciplines perform actively in the Attitudes and Values dimension but are generally weak in Knowledge and Understanding, presenting a typical contrast of “High Willingness, Low Cognition”. This structural imbalance reveals a systemic deviation in current education within these universities: excessive focus on the vertical deepening of professional skill while neglecting the horizontal expansion of global vision; and an emphasis on value advocacy at the ideological level while lacking teaching mechanisms to transform global knowledge into practical capabilities.

5.1.2 Significant influence of key factors like international exchange

International exchange experience has a significant “moderate effect” on students’ global competence, among which 1–6 months of short-term international courses show the most obvious improvement in dimensions such as skill and action willingness, indicating that highly structured immersive experiences have more educational value than mere visits. At the same time, the mother’s education level, as a representative indicator of family cultural capital, has a significant positive impact on students’ knowledge understanding, cross-cultural skill, and action willingness, highlighting the long-term shaping function of the family socialization process on international literacy.

5.1.3 Disciplinary differentiation

The global competence of students from different disciplines shows significant differentiation. Science and engineer-

ing students are weaker in the “Knowledge and Understanding” dimension, particularly showing obvious shortcomings in the systematic cognition of globalization issues; while liberal arts students are relatively insufficient in the “Action and Willingness” dimension, needing stronger abilities to transform concepts into practice. This difference reflects the internal limitations of disciplinary training models: science and engineering education emphasizes technical rationality and professional depth but weakens understanding of the global socio-cultural context; liberal arts education, while emphasizing values and critical thinking, lacks training in transforming abstract topics into operable solutions.

5.2 Research insights

Based on the structural imbalance, key influencing factors, and disciplinary group differences found in the empirical research, this study proposes the following three systematic improvement paths from the perspective of educational intervention.

5.2.1 Reconstruct the curriculum system to bridge the structural gap between cognition and ability

The root of the “High Willingness, Low Cognition” contradiction in the global competence of undergraduates in universities with emerging engineering disciplines lies in the separation between global literacy education and the professional curriculum system. Therefore, a systematic reform of the curriculum from “Value Advocacy” to “Capability Construction” must be promoted. The core path lies in promoting the deep coupling of global literacy and professional education. In terms of curriculum setting, we should move beyond simply adding “international” general education courses and instead promote the internal globalization of professional courses. Specifically, international technical standards, cross-cultural engineering ethics cases, and product adaptability norms for specific regional markets can be systematically embedded into professional core courses, allowing students to understand the global context of engineering practice during knowledge internalization. Simultaneously, modular and project-based courses themed on “Global Engineering Challenges” should be developed to guide students in using multi-disciplinary knowledge to solve complex problems. In terms of teaching paradigms, contextual and experiential teaching should be widely adopted. By introducing real cases from multinational corporations, simulating international project collaboration, and forming cross-cultural virtual teams, a “near-practice” learning environment is created. This approach effectively compels the application of knowledge and the transfer of skills, synchronously tempering cross-cultural communication, critical thinking, and global collaboration capabilities during problem-solving. This effectively bridges the “Attitude Recognition” to “Practical Ability” gap, addressing shortcomings in cognition and skills.

5.2.2 Optimize the mobility mechanism to enhance the educational effectiveness of international exchanges

Research shows that international exchange experience, especially 1 to 6 months of short-term study, has a significant “moderating effect” on multiple dimensions of students’ global competence. This suggests that universities need to shift from pursuing the scale of exchange to focusing on quality and structured support. The key to optimization lies in building a “whole-process empowerment” support system and a “multi-type simultaneous” project structure. In project design, a gradient international mobility system should be established: use short-term study visits to expand the student participation base; use international curriculum projects, semester exchange projects, and academic year joint training projects as the backbone of training; and use overseas scientific research training and international organization internships to cultivate top-tier talent. Simultaneously, a home-school collaborative education mechanism should be established to include the family in the support network for students’ international development. Through parent briefing sessions, international project guides, and sharing student exchange achievements, family understanding and support can be enhanced, forming a beneficial “School-Family-Student” ecosystem that jointly assists the continuous development of students’ global literacy.

5.2.3 Promote interdisciplinary integration to break the limitations of humanistic vision among science and engineering students

Research indicates that science and engineering students are significantly weaker than liberal arts students in global knowledge, humanistic vision, and problem awareness, exposing the limitations of a model focused solely on technical rationality. The intrinsic requirement of emerging engineering construction is to break down disciplinary barriers and cultivate composite talents who can manage complexity. Recent international research has emphasized that higher education should foster interdisciplinary competence, global citizenship, and ethical responsibility to prepare students for complex global challenges in the digital and post-pandemic era (UNESCO, 2023). This perspective further highlights the necessity of integrating humanities education into engineering talent cultivation in the era of globalization. The fundamental strategy lies in achieving the complementarity and integration of thinking modes through institutionalized interdisciplinary learning. First, credit systems should be reformed to establish mandatory interdisciplinary study modules, requiring science and engineering students to take humanities and social science courses such as international relations, engineering sociology, and comparative culture to construct the multi-dimensional knowledge framework needed to understand global issues. Second, Interdisciplinary Project-Based Learning (PBL) themed around “Global Challenges” should be designed and implemented. For example, teams composed of students from engineering, design, and public management could focus on “Inclusive Design of Smart Cities”. In this collaboration, science and engineering students are no longer pure technology suppliers but must redefine the value premises

and application boundaries of technical solutions in dialogue with social perspectives. This practice aims to catalyze their transformation from technical executors to innovators with social insight, ultimately shaping a worldview with both technical depth and humanistic breadth.

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Conflict of interest

The authors declare no competing interest.

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