Influence of Training Mode on Professional Identity of Engineering Ph.D. Students: The Moderating Role of Disciplinary Differences

Dr. Lina Wei, Peking University

Lina Wei, PhD in Management, Postdoctoral Fellow, Assistant Researcher, Graduate school of education, Peking University. Her research focuses on engineering education and postgraduate education.

Influence of training mode on professional identity of Chinese engineering PhD students - Mediating effect analysis of different disciplinary

Objectives: The reform and innovation of the recruitment mechanism constitute a significant breakthrough in advancing the reform of the engineering doctoral education system. By focusing on the micro-issue of professional identity of engineering PhD students, we can gain a deeper understanding of their learning experiences, decipher the underlying reasons behind the "fleeing from engineering" phenomenon, explore the conditions fostering the appeal of engineering majors, and ultimately propel the long-term growth of engineering education.

Methods: Drawing from the 2022 Chinese Doctoral Graduates Survey, which encompassed 4,983 engineering PhD students, this study employed the least squares (OLS) regression model to delve into the facilitating conditions for the development of professional identity among engineering PhD candidates. Additionally, it aimed to assess the impact of training modes on the professional identity of engineering PhD students, considering disciplinary disparities.

Results and discussion: On one hand, the professional identity of engineering PhD students in non-through training is significantly stronger than that of engineering PhD students in through-type training. This disparity is evident across various levels of through-type training, with the degree of through-type training inversely proportional to the performance of professional identity of engineering PhD students. On the other hand, the professional identity of engineering PhD students is affected by the characteristics of the disciplines to a certain extent, and the training mode has a significant effect on the professional identity of PhD students in applied engineering disciplines, while it has no significant effect on PhD students in basic engineering discipline.

Conclusions: (1) There are differences in the professional identity of engineering PhD students in through-type training and non-through training, and the professional identity of engineering PhD students in non-through training is higher. (2) There are differences in the professional identity of engineering PhD students of different training types, and the higher the degree of coherence, the lower the performance of professional identity. (3) There are differences in the professional identity of engineering PhD students in applied engineering disciplines and basic engineering disciplines, and the cultivation mode significantly affects the professional identity of PhD students in applied engineering disciplines, but has no significant effect on PhD students in basic engineering disciplines. Based on this, the study makes suggestions that focus on institutional support and professional identity construction of

engineering disciplines.

Keywords: engineering PhD students; training model; professional identity; disciplinary differences

1. Formation of the research questions

It has been observed that engineering students tend to lose interest in their field over time. This apathy towards engineering may lead to a "xenophobic" and "demanding" mindset, subsequently causing them to disengage from the field. [1] Additionally, a more profound issue of student attrition has been identified.[2] The professional identity of engineering PhD students is not only integral to their academic and professional success, but also acts as a driving force for technological innovation and advancement. As engineering disciplines become increasingly diverse and complex, distinct training methods and disciplinary characteristics are playing a larger role in shaping the professional identity of these students. However, despite a large number of studies focusing on doctoral training or professional identity, there is a relative lack of research on how engineering PhD students form professional identity in different disciplinary contexts.

In terms of the doctoral training process, China's doctoral enrollment mode has undergone a gradual transformation including doctoral degree programs, master's and doctoral degree programs and doctoral programs for high school graduates [3]. Through training can not only improve the efficiency of talent training[4], also effective in enhancing the continuity of research training and practice for doctoral students.[5] To further advance the reform of engineering doctoral enrollment, it is imperative to clarify the question of the distinct impact of through-type and non-through training on the development of engineering PhD students' professional identity.

Focusing on the micro-issue of the impact of the differences in training modes on the professional identity of engineering PhD students in different disciplinary contexts helps to deeply understand the learning experience of engineering students and how to effectively shape the attractiveness of engineering majors. Furthermore, it also offers explanations for the reasons behind the "fleeing from engineering" and provides theoretical and practical guidance for optimizing the training mode of engineering PhD students. The enhancement of the professional identity of engineering PhD students is a prerequisite for attracting more high-quality talents to enter the field of engineering, and it is also one of the core objectives in the reform of engineering education across various countries.[6]

2. Literature review

2.1 Professional identity and its connotation for engineering PhD students

Some scholars define identity as a subjective assertion of personal consistency, in alignment with others[7], and the orientation of identities and roles in society.[8] Professional Identity refers to the acceptance and recognition of learners' specialty and their willingness to learn and explore with positive attitude and active behavior.[9,10] The process of developing a professional identity encompasses cognitive, affective, social interaction, and behavioral aspects, including self-concept, values, beliefs, and skills. This long-term and dynamic journey typically involves multiple stages of exploration, selection, initiation, and practice. A robust professional identity is linked to increased career satisfaction, enhanced teamwork and sustained professional development.

The professional identity of doctoral students is defined by their acknowledgment and recognition of their major through rigorous study, research, and practical application of their academic disciplines. Furthermore, it reflects their eagerness to proactively adhere to professional and occupational norms, and to pursue this career as a personal lifelong goal.[11,12] Identity in the field of engineering education also focuses on the overall process of an individual's transformation from an "outsider" to a community in the field of engineering, such as awareness and perception of the content of specialized knowledge in engineering, the significance of the profession, the characteristics of the engineer's profession, and the functions and status of the society.[13,14] Drawing from the two facets of engineering students' self-identity and professional identity, certain scholars have delved into the dual dimensions of these identities, exploring how students' definitions of self and their understanding of engineering careers evolve as they progress through their learning and ultimately become part of a professional community through the constant comparison and negotiation of these two identities.[15]

The professional identity of engineering PhD students is a professional identity for doctoral students in engineering or applied sciences. This identity includes not only advanced technical knowledge and analytical skills, but also emphasizes practicality, innovation, and problem solving. engineering PhD students typically progress from mastery of basic courses and laboratory skills to deeper involvement in specific projects or research. This process involves various factors, such as mentoring, laboratory culture, teamwork, and even interaction with industry. Relevant studies have shown that environmental factors play a significant role in the development of professional identity among doctoral students.[16-18] Compared to other disciplines, engineering Ph.D. students may place more emphasis on practical applications and industrial collaborations, which may also be part of their professional identity. The professional identity of engineering students is the driving force that keeps them learning and developing in the engineering field.[19] A strong professional identity for engineering PhD students not only propels academic success, but also enhances the integration with industry, ultimately career opportunities.

In recent years, there is a more serious phenomenon of engineering students fleeing

away from their training programs[20]. The professional identity of engineering PhD students is under a growing concern.

2.2 Influence of training mode on professional identity of engineering PhD students

China has implemented a three-tiered degree system of which bachelor, master and doctoral degree being recognized as three independent degrees. The education of master's and doctoral degrees is normally conducted in sequential stages, fostering a gradual progression between them. Consequently, the training model for doctoral students can be categorized into two types: through-type training and non-through training, depending on the design of the training system. Through-type doctoral training includes two training programs: integrated master-doctor degree program and doctoral program for undergraduates [21]. The non-through doctoral training separates the master's degree training and the doctoral training from each other. Students first complete a master's degree before entering the doctoral training stage. This model emphasizes the independence and integrity of the master's and doctoral stages, with each stage having its own specific training objectives and requirements.

The characteristics of training mode should be in line with the requirements of modern high-level talents to have a high accumulation of knowledge and continuity of scientific research, which is conducive to the cultivation of high-level talents and improve the quality of cultivation.[22] Compared with non-through doctoral training, through-type training has the following characteristics: firstly, it helps to simplify the overlapping training links, optimize the training process, shorten the training cycle of postgraduates as a whole, and improve the efficiency of postgraduates' cultivation.[23] Furthermore, the through-type training contains extensive research time ensures the consistency of the doctoral students' scientific research activities. This allows them to select more extensive and complex topics, especially in fields that necessitate a strong connection between academic coursework and scientific research, and where the production of results requires a significant amount of time, such as engineering, medical science, and agronomy.[24] Thirdly, through-type training usually contains training of cross-disciplinary sections which provides opportunities of integration of knowledge production in the future. Fourthly, the relatively long training cycle of the through-type training provides sufficient time for the implementation of innovative programs of postgraduate education, such as joint training of doctoral students at home and abroad, and visits of doctoral students to study at home and abroad.[25] Fifthly, under the mode of through-type training, the diversion mechanism of doctoral training can be effectively promoted and implemented, the flexibility and vitality of doctoral training can be enhanced, and the quality control of the key nodes in the process of doctoral training can be put into practice.[26]

The integration of undergraduate and graduate programs can reflect the depth and intersectionality of the disciplines, and allow students to understand the deeper

knowledge structure of their own disciplinary fields.[27] However, the current training mode of undergraduate and graduate students in China is relatively solidified. However, the current cultivation mode of China's undergraduate and postgraduate stages is relatively solidified, which can't give good play to individual interests and ability levels, resulting in students' low initiative in theoretical learning and insufficient motivation for professional innovation ability training.[28] Obstructing the promotion of professional identity. Xinhong Wang et al. conducted an empirical study on the process of long-study direct doctoral students from selection to exit, and found that long-study doctoral students' academic experience varied greatly, their willingness to obtain a doctoral degree showed a divergent trend, and they also faced greater non-academic pressure.[29,30]

2.3 Disciplinary differences in engineering doctoral training models

The applied engineering disciplines refer to those branches of engineering that focus on the practical application of engineering principles and techniques to solve real-world problems. These disciplines involve the integration of theoretical knowledge with hands-on experience to design, develop, implement, and optimize engineering systems, products, or processes. They cover a wide range of areas, including but not limited to mechanical engineering, electrical engineering, civil engineering, chemical engineering, and computer engineering, among others. The basic engineering disciplines refer to the fundamental areas of engineering that provide the core knowledge and principles underlying all engineering practices. These disciplines serve as the foundation for the more specialized and applied branches of engineering. They typically include mathematics, physics, and the principles of engineering design, analysis, and optimization. The basic engineering disciplines are essential for developing a solid understanding of the fundamental concepts, theories, and methodologies that are necessary for engineering professionals to solve complex engineering problems and create innovative solutions. Different discipline may be best suited to a specific mode of training. For instance, in natural sciences and engineering, experimentation and teamwork hold greater importance, whereas in social sciences and humanities, individual independent research is more highly valued. For instance, after analyzing the survey data of supervisors from 52 universities in China, Niu Menghu discovered that different disciplines have diverse preferences for doctoral enrollment. He also observed that natural sciences are more suitable for direct PhD and master's and doctoral degree programs, as well as other through-training methods.[31] Therefore, the difference of disciplines is another important issue facing the training of doctoral students. The major engineering disciplines cover a wide range of engineering disciplines, from basic engineering disciplines to applied engineering disciplines. These different disciplines possess their own unique academic and vocational needs, and therefore require different training modes. For example, in basic engineering disciplines, research is usually more focused on theory and experimentation, while in applied engineering disciplines, it is more focused on practical applications and problem solving. Such disciplinary

differences may modulate the impact of training modes on the professional identity of engineering PhD students.

In summary, studies have analyzed the connotation and influence mechanism of professional identity in depth, but there is a lack of studies focusing on the professional identity of engineering PhD students, and there is still a need for more in-depth empirical analysis of the differences between professional identity and cultivation modes, and between cultivation modes and disciplines. From the perspective of research, due to the limitation of research data, the comparison of doctoral students of different recruitment methods focuses on the subjective perception dimensions such as motivation, willingness to study and academic training.[32] This study tries to explore the mechanism of "professional identity and discipline difference in training mode" from the professional identity of engineering PhD students. The present study attempts to explore the mechanism of "professional identity-disciplinary differences in training mode" from the perspective of professional identity of engineering PhD students, and tries to respond to the following questions through empirical analysis.

Question 1: What is the current status of professional identity of engineering PhD students? Are there differences in the professional identity of engineering PhD students in different disciplines?

Question 2: How does the training mode impact the professional identity of engineering PhD students, and what type of training mode is suitable for different engineering PhD students?

3. Research design

3.1 Research tools and variable settings

To gain a comprehensive understanding of the current training experience of Chinese doctoral students, the China Doctoral Education Research Center launched by Peking University, commissioned by the Ministry of Education's Department of Degree Administration and Graduate Education, has been conducting the National Postgraduate Training Quality Feedback Survey Project since 2016. This national survey focuses on recent doctoral graduates. The team developed the National Doctoral Graduates Survey Questionnaire as a survey tool, drawing from existing survey questionnaires. The questionnaire uses a five-level Likert scale, ranging from 1 to 5, to assess the degree of agreement or disagreement with statements.

Engineering, as a discipline, has evolved through the application of fundamental scientific principles like mathematics, physics, and chemistry, while integrating them with technical know-how acquired through practical production experiences. To offer a clearer understanding of professional identities, institutional backing, and the

distinctions among various engineering students, this paper organizes and contrasts engineering disciplines. The sample is divided into two categories: basic engineering disciplines and applied engineering disciplines. The basic engineering disciplines encompass engineering-related majors in mathematics and science, such as engineering physics, nuclear engineering and technology, polymer materials and engineering, etc. Additionally, the Strong Foundation Program offers engineering majors, where colleges and universities adopt the "basic science + engineering articulation majors" model. This includes combinations of theoretical and applied mechanics with civil and water conservancy engineering, ocean engineering, energy and power engineering, water resources engineering, and more. Other options include marine Engineering, energy and power engineering, vehicle engineering, aerospace engineering, as well as mathematics and science basic disciplines, environment and energy application engineering, environmental engineering, software engineering, industrial engineering, etc. These programs award double degrees in engineering and science. Applied engineering disciplines include architecture, civil Engineering, environmental and chemical engineering, mechanical, aeronautical and power engineering, energy and electrical engineering, and automation.

According to the above classification standards, in the process of data processing, 0801 Mechanics (which can be awarded engineering and science degrees), 0809 Electronic Science and Technology (which can be awarded engineering and science degrees), 0812 Computer Science and Technology (which can be awarded engineering and science degrees), and 0831 Biomedical Engineering (which can be awarded engineering, science and medical degrees) are regarded as the basic engineering disciplines under the engineering disciplines, and the rest of the 35 disciplines are regarded as the applied engineering disciplines. The remaining 35 disciplines are regarded as applied engineering disciplines.

In addition, with reference to the existing studies, this paper included the factors of gender, whether they are members of the CPC, whether they have extended their studies, the level of the institution, and whether they have joined the "Engineer Excellence Cultivation Program" in the control variables. The measurements and descriptive statistics of all variables are shown in Table 1.

Table 1 Measurement of variables

Variables	**Description of variables**
Professional identity	Assignment of scores to the scale "How has your professional identity changed during your doctoral studies?"
Training model	1 for "direct undergraduate degree" or "master's degree" and 0 for "general entrance examination".
Type of discipline	1 for basic engineering, 0 for applied engineering
Gender	1 for men, 0 for women
Communist Party member	1 for CPC members, 0 for non-CPC members

Delay graduation	1 for delayed graduation, 0 for non-delayed graduation
Type of school	Double first-class university are assigned a value of 1, and other colleges and universities are assigned a value of 0.
Engineer Excellence	The value of "Excellent Engineer Training Program" is 1, otherwise it is 0.

3.2 Sample

The data of this study came from the results of the 2022 survey, which obtained 22,382 valid questionnaires from the survey of doctoral graduates, and the validity rate of the questionnaires was 89.2%. Among them, 7,769 questionnaires for engineering PhD students and 7,454 questionnaires for full-time engineering PhD students (the actual effective sample size in the study is 4,984). This study takes the questionnaire of full-time engineering PhD students as the object of analysis. The results of the reliability test show that the survey data are of high quality and good representativeness, and can reflect the overall situation well. The sample distribution are shown in Table 2.

Table 2 Sample distribution

Variable name		Sample size	Percentage (%)
Gender	male	4987	66.9
	women	2467	33.1
Type of school	Double first-class university	3296	55.8
	Non-double first-class university	4158	44.2
Training model	Undergraduate Direct	944	12.7
	master's degree program	2649	35.5
	General Recruitment Examination (GRE)	3861	51.8
Type of discipline	Basic Engineering	1431	20.6
	applied engineering	5502	79.4

3.3 Modeling

For the influence of training mode on professional identity of engineering PhD students, a multiple regression analysis model was constructed with professional identity of engineering PhD students as the dependent variable, training mode as the independent variable and discipline category as the moderating variable, while controlling for individual characteristics of the students, institutional background and other variables, and the moderating effect of discipline category was analyzed by using subgroup regression. According to the characteristics of the explanatory

variables, logistic linear regression was used for the quantitative analysis of this study.

4. Analysis of results

4.1 The overall situation of the identification of engineering PhD students' specialties

Overall, the average score of professional identity of engineering PhD students is 4.04, and in terms of cultivation mode, the proportion of through training is 48.2%.The relevant results are shown in Table 3.

Table 3 Descriptive statistics of variables

	N	minimum value	maximum values	average value	(statistics) standard deviation
Professional identity	7454	1	5	4.041	0.929
Training model	7454	0	1	0.482	0.500
Type of discipline	6933	0	1	0.206	0.405
Distinguishing between the sexes	7454	0	1	0.669	0.471
Communist Party member	7454	0	1	0.678	0.467
Delay completion	7454	0	1	0.471	0.499
Type of school	7454	0	1	0.442	0.497
Excellent Engineer Education and Training Program	5353	0	1	0.015	0.120

4.2 Comparison of professional identity between through-type training and non-through training of engineering PhD students

First, let's take a look at the overall differences. The table 4 shows that after controlling for the influencing factors of discipline category, individual characteristics of engineering PhD students and cultivation characteristics of engineering PhD students, the professional identity of through-training engineering PhD students is significantly lower compared with that of non-through-training engineering PhD students. This indicates that the professional identity of non-through-training engineering PhD students is significantly higher than that of through-training engineering PhD students in general.

In terms of control variables, the professional identity of engineering doctoral degree holders varies significantly among different levels of institutions, whether or not they have extended their graduation, and whether or not they have been selected for the "Engineer Excellence Program". Specifically, the professional identity of engineering PhD students in universities of Double first-class university construction is significantly lower than that in other universities; the delayed graduation has a

significant negative correlation with the professional identity of engineering PhD students; the professional identity of engineering PhD students who have been awarded the "Excellent Engineer Program" is significantly higher than that of engineering PhD students who have not been awarded the "Excellent Engineer Program". The professional identity of engineering PhD students with "Excellent Engineer Program" is significantly higher than that of engineering PhD students without "Excellent Engineer Program".

Table 4 Comparison of professional identity of engineering PhD students trained in a through-type and non- through way

	Beta	t	p
Constant	4.365	58.259	0.000
Through-culture	-0.173	-6.651	0.000
Basic Engineering	-0.062	-1.962	0.050
a male	-0.059	-2.161	0.031
Communist Party member	0.151	5.454	0.000
Delay completion	-0.114	-4.391	0.000
Double first-class university	-0.188	-7.197	0.000
Engineer Excellence Program	0.253	2.384	0.017
N	4984		
R^2	0.030		
F	22.058		

4.3 Comparison of professional identity of engineering PhD students of different coherence types

After controlling for relevant influencing factors, the professional identity performance of engineering PhD students with different degrees of through-training is relatively lower compared with that of non-through-training doctoral students, and on the whole, the higher the degree of through-training, the lower the performance of professional identity. The results are shown in Table 5.

Table 5 Comparison of professional identity of engineering PhD students of different coherence types

	Beta	t	p
Constant	4.237	90.668	0.000
Undergraduate Direct	-0.206	-5.045	0.000
Master's degree program	-0.081	-5.729	0.000
Type of discipline	0.062	1.968	0.049
a male	-0.058	-2.145	0.032
Communist Party member	0.151	5.471	0.000

Delay completion	-0.114	-4.407	0.000
Double first-class university	-0.181	-6.762	0.000
Engineer Excellence Program	0.256	2.408	0.016
N	4984		
R^2	0.030		
F	19.440		

4.4 Comparison of professional identity of engineering PhD students in different discipline types

After controlling various factors, including discipline category, individual characteristics of engineering PhD students, and cultivation characteristics of engineering PhD students, it was observed that the professional identity performance of through-training engineering PhD students in applied engineering disciplines was significantly lower compared to non-through-training doctoral students. Interestingly, the difference in professional identity performance between through-training engineering PhD students in basic engineering disciplines and non-through-training doctoral students was not statistically significant. This indicates that the selection of training mode does not have a substantial impact on the professional identity of doctoral students in basic engineering disciplines. The relevant results are shown in Table 6.

Table 6 Comparison of professional identity of engineering PhD students in different discipline types

	Basic Engineering			Applied engineering		
	Beta	t	p	Beta	t	p
Constant	3.995	51.732	0.000	4.167	99.591	0.000
Through-culture	-0.079	-1.484	0.138	-0.196	-6.629	0.000
a male	0.196	3.541	0.000	0.020	0.656	0.512
Communist Party member	0.168	3.003	0.003	0.150	4.731	0.000
Delay completion	-0.158	-2.952	0.003	-0.10	-3.369	0.001
Double first-class university	-0.083	-1.547	0.122	-0.217	-7.273	0
Engineer Excellence Program	0.510	1.862	0.063	0.220	1.905	0.057
N	1067			3915		
R^2	0.032			0.032		
F	5.785			22.906		

5. Conclusions and recommendations

Based on the questionnaire survey of 4984 engineering students, this paper shows the current status of institutional support, professional identity, and career development among engineering PhD students. Furthermore, it examines the relationship between

these elements. The following results were found:

5.1 Findings

Firstly, the professional identity of engineering students is strong, and factors such as grades, genders and disciplines will have an impact on the professional identity of engineering students.

Secondly, there are differences in the professional identity of engineering PhD students in through-training and non-through-training, with those in non-through-training possessing a stronger professional identity. The professional identity of engineering PhD students varies depending on the type of training received, and as the level of coherent training increases, the weaker the professional identity of engineering students becomes. The professional identity of engineering students acts as an important mediator in the impact of institutional support on their career development. In statistical terms, institutional support exerts a complete influence on the career development of engineering students solely through their professional identity.

Thirdly, there are differences in the professional identity of engineering PhD students in applied engineering disciplines and basic engineering disciplines, and the training mode significantly affects the professional identity of doctoral students in applied engineering disciplines, however, it does not have a significant impact on doctoral students in basic engineering disciplines.

5.2 Policy recommendations

Firstly, it is imperative to establish distinct training models and cultivate a professional identity among students pursuing basic engineering disciplines and traditional application-oriented fields.
Secondly, there is a need to enhance the integrated training of engineering PhD students. However, the study's findings revealed that through-training did not outperform non-through-training in terms of effectiveness.
Thirdly, we must amplify the promotion of engineering's role in enhancing societal welfare and bolster the soft power and appeal of engineering majors. Overall, while engineering students are satisfied with the material resources of their school infrastructure, this infrastructure falls short in fostering their professional identity and career development.

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