A Study on Factors Affecting the Training Efficiency of Specialized Doctoral Programs: An Empirical Study Based on a Local University

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Abstract: The doctoral talent training program addressing national special needs is a significant development in the reform of China's degree authorization system. The university in question (hereafter referred to as 'University X') was one of the first pilot institutions to offer a PhD program in Control Science and Engineering, which it has provided for over a decade. It was officially approved as a degree-awarding institution in 2024. Using full-sample data on 75 doctoral students enrolled between 2013 and 2022, this study employs a three-dimensional analytical framework of 'institution–environment–individual' to empirically examine the program's training efficiency. Findings reveal an overall graduation rate of 42.7% (32/75), with graduates completing their studies in an average of 60.9 months—exceeding the standard academic duration by 2 years. Three dimensions can explain differences in training efficiency. At the institutional level, graduation requirements must be aligned more closely with the standard academic duration; raising these requirements significantly reduces the graduation rate (p=0.002), but does not significantly shorten graduates' study duration (p=0.088). At the environmental level, there is significant variation in supervisor effectiveness (p = 0.025): students supervised by off-campus supervisors in administrative roles have a graduation rate of only 9.1%. At the individual level, the impact of prior disciplinary background is U-shaped. At the same time, its effect on study duration is insignificant; students from different disciplinary categories perform better than those from the same category. There is no significant difference in the graduation rate between designated and non-designated students, but the former have a significantly longer study duration (p = 0.001). This study summarises the training experiences of special-demand programs and provides empirical evidence to optimize formal doctoral training.

Keywords: Doctoral Special Demand Program; Training Efficiency; Screening Theory; Academic Community; Student Development

1. Introduction

The 'Doctoral Talent Training Program Serving National Special Needs' was launched in 2011 to cultivate high-caliber talent urgently needed by the country. In 2012, 35 universities were approved as the first cohort of pilot institutions. One of these was University X, which, based on its Control Science and Engineering discipline, undertook the task of training doctoral students in transportation. It was officially approved as a degree-awarding institution for doctoral degrees in 2024. Training efficiency is a key indicator of the quality of doctoral education, as reflected in core metrics such as graduation rates and time to degree completion. According to educational statistics published by the Ministry of Education, the national doctoral graduation rate in 2024 was 43.5% [1,2]. Recent cross-national studies have shown that institutional-level training system designs significantly affect doctoral completion rates [3]. Xu and Wei point out that the evaluation of the quality of doctoral education is trending towards 'providing support for individual doctoral students' [4].

Existing research can be summarised into four categories: individual, supervisor, training process, and institution. The individual dimension focuses on academic preparation and research motivation [5,6]. Recent studies have also revealed an increasing focus on the mental health of doctoral students, with a significant proportion experiencing moderate to severe anxiety symptoms [7-9]. The supervisor dimension emphasizes the effectiveness of mentoring models. Domestic research has also revealed a non-linear relationship between supervisory load and the quality of doctoral training [10], as well as the moderating role of supervisory behavior in doctoral students' academic output [11]. The training process dimension analyses the role of curriculum systems and academic climate [12]. Against the backdrop of the transformation of knowledge production models, the degree of interdisciplinary integration is particularly noteworthy — interdisciplinary training has become an important factor affecting the efficiency of doctoral research [13]. Based on a national survey of doctoral graduates, Xie and Xu found that interdisciplinary dissertation research significantly increases the risk of delayed graduation [14]. The institutional dimension focuses on graduation requirements and process management [15]. While these studies offer multiple perspectives, limitations remain, including the absence of examination of multi-level factor interactions and the lack of consideration of the dynamic coupling among institutions, environments, and individuals. In response to the aforementioned limitations and building on Xie and Shen's argument, training institutions should adopt more inclusive and supportive management policies towards doctoral students, provided that a reasonable extension is granted to their graduation date [16]. Based on institutional practices, this paper presents a three-dimensional 'system–environment–individual' analytical framework (Figure 1) to analyze the multi-layered mechanisms that influence training efficiency.

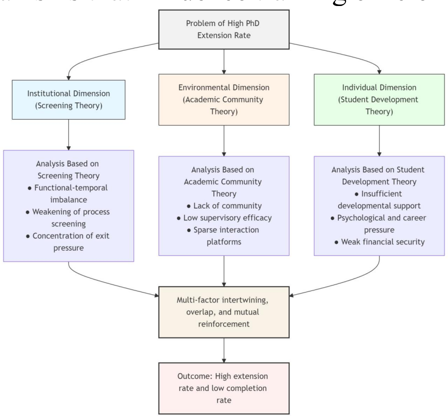

Figure 1. Three-Dimensional Analytical Framework of Institution-Environment-Individual

2. Research Design and Data Methods

In 2012, University X was approved for the doctoral special demand program, focusing on the field of 'Intelligent Control of Megacity Road Traffic', with a standard academic duration of three years. The current graduation requirement is the publication of three high-level papers (at least two of which must be in SCI/EI-indexed journals). These requirements have been adjusted during program implementation: cohorts from 2013 to 2015 were required to publish at least one SCI/EI paper, whereas cohorts from 2016 onwards were required to publish at least two.

This study's data cover ten enrolment cohorts from 2013 to 2022. After excluding two students who dropped out, the effective sample size is 75, of whom 32 have graduated. Information on doctoral supervisors and the training program's curriculum is derived from official public data on the university's website. Dissertation data were derived from the degree information submission database from 2017 to 2025, and basic student data were obtained from the doctoral student registration and academic record databases on the Ministry of Education's China Higher Education Student Information (CHSI) platform from 2013 to 2025.

This study uses quantitative methods, such as descriptive statistics, chi-square tests, and Kaplan-Meier survival analysis, to examine statistical patterns and the mechanisms influencing doctoral training efficiency in the special demand program.

3. Empirical Findings and Mechanism Analysis

3.1 Overall Description of Doctoral Training Efficiency in the Special Demand Program

Descriptive statistics for doctoral students enrolled in the special demand program between 2013 and 2022 (see Table 1) show that, after excluding two students who dropped out, the effective sample size is 75. Of these students, 32 have graduated, resulting in an overall graduation rate of 42.7%. Only 5.3% of students graduated on time, while 37.3% graduated after experiencing a delay. The average study duration for graduates is 60.9 months (SD = 21.8), which is almost two years longer than the standard three-year academic duration of 36 months. The average study duration for non-graduates is 56.1 months (SD = 19.9), similar to that of graduates.

This suggests that current students also face a lengthy training period.

By enrolment cohort, all students in the early cohorts (2013–2015) graduated, but their average study duration ranged from 45 to 66 months (3.8–5.5 years), with none graduating on time. Graduation rates for cohorts after 2016 show a clear decline: 80.0% in 2016, 75.0% in 2017, 42.9% in 2018, and 25.0% in 2019. This downward trend coincides with an increase in graduation requirements (from one SCI/EI paper to two, starting in 2016).

Table 1. Overall Training Status of Doctoral Students in the Special Demand Program

Enrollment Year	Number Admitted	Graduated	Not Graduated	On-time Graduation Rate (%)	Delayed Graduation Rate (%)	Average Study Duration of Graduates (months)	Average Study Duration of Non-graduates (months)
2013	2	2	0	0.0	100.0	45	-
2014	2	2	0	0.0	100.0	60	-
2015	3	3	0	0.0	100.0	66	-
2016	5	4	1	0.0	80.0	92.3	108
2017	8	6	2	0.0	75.0	77.2	96
2018	7	3	4	0.0	42.9	59	84
2019	8	2	6	0.0	25.0	46.5	72
2020	11	6	5	18.2	36.3	46	60
2021	12	2	10	0.0	16.7	47.5	48
2022	17	2	15	11.8	0.0	34	36
Total	75	32	43	5.3%	37.3%	60.9	55.5

Note: the admission numbers exclude one dropout from each of the cohorts 2018 and 2019. 'On-time graduation' refers to a study duration of ≤36 months. The average study duration of graduates is: 60.9 months (5.1 years). Average study duration of non-graduates: 55.5 months (approximately 4.6 years).

3.2 Institutional Dimension: Alignment between Graduation Requirements and Academic Duration

Screening theory emphasizes that the temporal configuration and node settings of educational screening affect the efficiency and fairness of talent allocation. The institutional design of University X’s special demand program exhibits the following characteristics:

3.2.1 Structural tension between graduation requirements and standard academic duration

The program requires the publication of three high-level papers (at least two in SCI/EI-indexed journals), which is extremely challenging to accomplish within three years. Doctoral students typically spend considerable time on experimental design, data collection, writing and revising papers, and participating in peer review, with each review cycle often lasting 6–12 months. Data show that graduates' average study duration is close to 61 months, indicating that the standard academic duration as a temporal constraint has been significantly weakened.

Notably, the training process at University X is designed such that students must first meet the publication requirement before submitting their dissertations for review. Since meeting the publication requirement is the main hurdle, the external dissertation review process is generally passed on the first attempt. Therefore, delayed graduation is primarily due to the time required to publish high-level papers rather than the dissertation review process.

3.2.2 Longitudinal evolution of the training program and increase in graduation requirements

A longitudinal comparison of the training program for cohorts from 2013 to 2022 (see Table 2) shows that graduation requirements have increased significantly, and this change is highly correlated with the changes in graduation rates shown in Table 1.

Table 2. Evolution of Key Provisions in the Doctoral Special Demand Training Program

Version	Applicable Cohorts	Graduation Requirement (SCI/EI papers)	Proposal Defense Timing	Title Keywords
V1	2013–2015	At least 1	2nd–3rd semester	Theory and Technology of Intelligent Control Systems for Megacity Road Traffic
V2	2016–2020	At least 2	3rd–4th semester	Same as above
V3	2021–2022	At least 2	3rd–4th semester	Control Science and Engineering

The chi-squared test revealed a highly significant difference in graduation rates between the various versions of the graduation requirements (Fisher's exact test, $p = 0.002$). The graduation rate for version V1 (requiring one SCI/EI paper; cohorts 2013–2015) was 100% (7/7), whereas the combined graduation rate for versions V2 and V3 (both requiring two SCI/EI papers) was 36.8% (25/68).

These results strongly suggest that the alignment between graduation requirements and standard academic duration is a core institutional factor affecting training efficiency. An independent-samples t-test shows that, on average, students under the higher requirement version (V2/V3) studied for longer (61.6 months, SD=23.0) than students under the lower requirement version (V1) (58.3 months, SD=17.8). However, this difference is not statistically significant ($t = 0.355$, $df = 30$, $p = 0.088$). This suggests that, while raising graduation requirements significantly reduces the graduation rate, it does not shorten the study duration of those who eventually graduate. Instead, it reveals a trend of lengthening (which may not be statistically significant due to the small sample size of V1).

At the same time, the timing of the proposal defense was adjusted from '2nd–3rd semester after enrolment' to '3rd–4th semester after enrolment', shifting the substantive screening node later and further reinforcing the institutional feature of 'postponed screening pressure'.

3.3 Environmental Dimension: The Role of Academic Community Support and Interdisciplinary Integration

According to the theory of the academic community, doctoral students' academic growth depends on a process of 'legitimate peripheral participation'. The level of academic community support within University X's special demand program significantly impacts training efficiency.

3.3.1 Variation in supervisory effectiveness

As of 29 September 2025 (the date of the most recent university academic degree committee meeting), 27 doctoral supervisors had supervised 75 doctoral students, 32 of whom graduated. In terms of supervisor characteristics, supervisor title (professor/associate professor) does not significantly affect graduation rates. However, the type of supervisor appointment and the presence of concurrent administrative positions noticeably impact supervisory effectiveness (Table 3).

Descriptive statistics show that the graduation rate of students supervised by off-campus supervisors is significantly lower than that of students supervised by on-campus supervisors. Four off-campus supervisors supervised 13 students, of whom only three graduated (a graduation rate of 23.1%), whereas 23 on-campus supervisors supervised 62 students, of whom 29 graduated (a graduation rate of 46.8%). Among the 23 on-campus supervisors, those with administrative concurrent positions had a student graduation rate of 52.9%, higher than that of those without administrative concurrent positions (39.3%). Of the four off-campus supervisors, the one without an administrative role had a student graduation rate of 100%, which was higher than that of the three supervisors with administrative roles (9.1%).

Table 3. Association between Supervisor Type and Student Graduation

Supervisor Type	Administrative Concurrent Position	Number of Supervisors	Number of Students Supervised	Number Graduated	Relative Graduation Rate	Average Study Duration of Graduates (months)
On-campus	Yes	11	34	18	52.9%	61.0
On-campus	No	12	28	11	39.3%	60.7
Off-campus	Yes	3	11	1	9.1%	54.0
Off-campus	No	1	2	2	100%	64.5
Total		27	75	32	42.7%	60.9

Note: The two students who dropped out are not included in the above statistics. Administrative concurrent positions include bureau director, division chief, and deputy division chief levels.

The chi-squared test revealed a highly significant difference in graduation rates across supervisor types ($\chi^2 = 9.355$, $df = 3$, $p = 0.025$). Students supervised by off-campus supervisors in administrative roles have a graduation rate of only 9.1%, which is significantly lower than that of students supervised by on-campus supervisors. This suggests that off-campus supervisors struggle to provide ongoing, specific guidance, with other faculty members in the research group often taking on their supervisory responsibilities, thereby disrupting continuity of supervision. Binary logistic regression analysis shows that, after controlling for other factors, students supervised by off-campus supervisors with administrative roles have only a 16.7% graduation advantage over those supervised by on-campus supervisors without administrative roles (Exp(B)=0.167, 95% CI: 0.030–0.940, $p=0.042$).

3.3.2 Interdisciplinary mechanisms and training efficiency

The degree of interdisciplinary integration is a key environmental factor that affects training efficiency. Although the training program of University X’s doctoral special demand program emphasizes interdisciplinary integration in several places, its institutionalized implementation mechanisms still need strengthening. From an institutional design perspective, the program provides a foundation for interdisciplinary training in four areas. Firstly, in terms of program orientation, the program explicitly defines urban road traffic control as an interdisciplinary field involving control science and engineering, traffic engineering, computer science, and communications. This establishes an interdisciplinary attribute from the outset. Secondly, in terms of curriculum design, given the diversity of students' disciplinary backgrounds, the program offers modules covering mathematics, control, computer science, and information processing. It allows students to take graduate courses at other universities. Thirdly, in terms of knowledge structure, the program includes a specific section on 'frontiers of disciplinary knowledge' that requires doctoral students to master interdisciplinary content, including complex traffic network analysis, traffic Internet of Things technology, and image-based traffic behavior analysis. Fourthly, regarding supervisor allocation, the program permits the supervisory and dissertation defense committees to include experts from relevant disciplines, thereby providing an institutional interface for interdisciplinary supervision.

However, the above institutional arrangements reflect more of a 'flexible advocacy' than 'rigid constraints'. The curriculum does not specify a minimum number of credits or courses for interdisciplinary electives. Instead, doctoral students selectively take courses based on their own disciplinary background and the knowledge requirements of their research, which may cause some students to adhere to their original disciplinary perspective due to path dependence. The participation of interdisciplinary supervisors is not mandatory, and the inclusion of experts from relevant disciplines in the proposal defense review panel or supervisory committee depends on contingent factors during implementation. There are also no institutionally arranged interdisciplinary academic exchange platforms in the training program.

This “conceptual advocacy” approach, which neglects institutional constraints, means that interdisciplinary training largely depends on students’ self-awareness and supervisors’ individual preferences. In disciplines such as control science and engineering, which are interdisciplinary by nature, insufficient interdisciplinary training may limit doctoral students' ability to acquire diverse research methods, thereby affecting their efficiency in addressing complex scientific problems.

3.4 Individual Dimension: Alignment between Student Characteristics and Development Support Systems

3.4.1 The relevance of the prior discipline to the doctoral discipline

The relevance of the prior discipline to the doctoral discipline is an important individual factor affecting training efficiency. Based on the relationship between the master's and doctoral disciplines (Control Science and Engineering), the 75 doctoral students were divided into three categories: same major (master's degree in Control Science and Engineering); same discipline category (master's degree in other engineering disciplines); and cross-category (master's degree in science, etc.). Descriptive statistics (Table 4) reveal significant disparities in training efficiency across these categories. Students with the same major have the highest graduation rate (60.0%) and an average study duration of 58.3 months (SD = 21.7). Cross-category students follow with a graduation rate of 42.9% and an average study duration of 61.6 months (SD = 18.0). Students with the same discipline category have the lowest graduation rate (28.9%) and an average study duration of 57.4 months (SD = 20.8).

The chi-squared test revealed a significant difference in graduation rates among students with different disciplinary backgrounds ($\chi^2 = 6.609$, df = 2, p = 0.037). The distribution exhibits a U-shaped pattern: students with the highest relevance (same major) and the lowest relevance (cross-category) have higher graduation rates than those in the middle group (same category). One possible explanation is that, although students in the same category have an engineering foundation, there is an implicit conflict between their original disciplinary paradigm and the research paradigm of control systems. This leaves them with a sense of being 'both familiar and unfamiliar' during the transition, requiring a longer adaptation period. Kaplan-Meier survival analysis shows no significant difference in the distribution of study duration among students with different prior disciplinary backgrounds (χ^2 = 3.231, df = 2, p = 0.199). Descriptively, the median study duration for students in the same category is 96 months (95% CI: 83.366, 108.634), which is higher than for the other two groups.

Table 4. Relevance between Prior Major and Doctoral Major

Relevance Type	Number Admitted	Number Graduated	Number Not Graduated	Relative Graduation Rate	Average Study Duration of Graduates (months)
Same major	30	18	12	60%	58.3 (SD=21.7)
Same category	38	11	27	28.9%	57.4 (SD=20.8)
Cross-category	7	3	4	42.9%	61.6 (SD=18.0)

3.4.2 Student status: designated vs. non-designated

Of the 75 effective samples, 28 are designated students (i.e., students who are employed while studying), accounting for 37.3% of the total. These students have a graduation rate of only 32.1% (9 students). In contrast, 47 are non-designated students, accounting for 62.7% of the total, and have a graduation rate of 48.9% (23 students). Among graduates, the average study duration for non-designated students is 55.3 months (approximately 4.6 years), whereas for designated students it is much longer at 75.3 months (6.3 years). This descriptive statistic only reflects the situation of graduates. To more accurately estimate the expected time to graduation for all designated students, this study employs Kaplan-Meier survival analysis, including censored data on non-graduates.

The chi-squared test indicates that the difference in graduation rates between designated and non-designated students is not statistically significant (χ^2 = 2.023, df = 1, p = 0.155). However, the median study duration for designated students, as determined by Kaplan-Meier survival analysis, is 96 months (95% CI: 81.675, 99.517), which is significantly longer than that for non-designated students (χ^2 = 13.418, df = 1, p = 0.001). This suggests that the main issue for designated students is not whether they will graduate, but how quickly they will do so. Their study duration is significantly longer than that of non-designated students, reflecting the fact that in-service doctoral students, due to the dual pressures of work and study, have fragmented research time and thus take much longer to complete their degrees.

3.5 Supplementary Analysis: Moderating Effects of Dissertation Topic and Research Direction

3.5.1 Research direction and characteristics of study duration

Analysis of dissertation information from the 32 doctoral program graduates shows that their research directions are concentrated in fields such as urban traffic control, autonomous driving, and networked control. These fields are highly consistent with the special demand program's training objectives. As shown in Table 5, the largest group of graduates (9, or 28.1%) specialized in urban road traffic control theory and signal control, completing their studies in an average of 59.6 months. The second largest group (5, or 15.6%) specialized in generalized traffic information interaction and fusion, completing their studies in an average of 52.4 months. The autonomous driving direction had the fewest graduates (4, or 12.5%), who completed their studies in an average of 38.5 months, significantly lower than in the other specialisms. Study duration varies considerably by research direction. The autonomous driving direction has the shortest study duration due to its close alignment with industrial demand and a relatively mature research paradigm. Traditional traffic control directions require extensive field data collection and simulation validation, leading to longer cycle times. The urban mixed traffic information perception and control direction has the longest average study duration (85.0 months) due to multi-source data fusion and complex scenario modeling, which involve greater research difficulty.

In terms of dissertation type, the highest proportion (23, or 71.9%) is accounted for by applied research, followed by basic research (9, or 28.1%). The average study duration for graduates of applied research is 61.3 months, compared to 60.2 months for graduates of basic research, indicating little difference. Regarding topic source, the largest group of graduates (13, or 40.6%) is supported by National Natural Science Foundation of China (NSFC) projects, with an average study duration of 67.5 months. This is followed by graduates supported by other projects, including non-funded and university-selected projects (12, or 37.5%), with an average study duration of 53.3 months, and graduates supported by National Key R&D

Program/973/863 Program projects (7, or 21.9%), with an average study duration of 62.9 months. This distribution suggests that, while national-level foundation projects offer substantial support, they are associated with greater research difficulty and longer timeframes.

Table 5. Distribution of Research Directions and Study Duration among Graduated Doctoral Students

Research Direction	Number	Percentage	Average Study Duration (months)	Study Duration Range (months)
Urban Road Traffic Control Theory and Signal Control	9	28.1%	59.6	45–96
Generalized Traffic Information Interaction and Fusion	5	15.6%	52.4	45–72
Autonomous Driving	4	12.5%	38.5	34–45
Networked Predictive Control/Networked Control Systems	4	12.5%	68.8	57–96
Urban Mixed Traffic Information Perception and Control	3	9.4%	85.0	72–93
Detection Technology and Automation Devices	3	9.4%	61.3	49–84
Information Security of Traffic Signal Control Systems	1	3.1%	93	93
Microgrid Operation and Planning	1	3.1%	57	57
Privacy Protection in the Internet of Vehicles	1	3.1%	46	46
Urban Intelligent Traffic Signal Control	1	3.1%	51	51
Total	32	100%	60.9	34–96

Note: some research areas build upon or overlap with the four core areas of the training program: Urban Road Traffic Control Theory and Signal Control; Urban Mixed Traffic Information Perception and Control; Generalized Traffic Information Interaction and Fusion; and Urban Traffic Real-time Simulation and Dynamic Decision-making. For instance, autonomous driving is covered by Generalized Traffic Information Interaction and Fusion, networked predictive control is covered by Urban Traffic Real-Time Simulation and Dynamic Decision-Making, and detection technology and automation devices are covered by Urban Mixed Traffic Information Perception and Control.

3.5.2 Cross-analysis of dissertation type and topic source

Further cross-analysis (see Table 6) reveals that graduates from different topic sources have different dissertation types. Of the 13 graduates supported by NSFC projects, 53.8% (7) conducted basic research and 46.2% (6) conducted applied research. Of the seven graduates supported by the National Key R&D Program/973/863 Program projects, all conducted applied research (100%). Of the 12 graduates from other topic sources, only 16.7% (2) conducted basic research, while 83.3% (10) conducted applied research. This distribution reflects the different orientations of the funding programs: the NSFC focuses more on basic theoretical innovation, whereas the National Key R&D Program emphasizes application orientation.

In terms of study duration, graduates of basic research supported by the NSFC have an average of 70.1 months, nearly six months longer than those of applied research from the same source (64.3 months). However, the difference is not significant due to the small sample size. Applied research graduates from other topic sources have the shortest average study duration (52.8 months), indicating that non-foundation projects generally have shorter lifecycles and are easier to complete.

Table 6. Cross-Analysis of Dissertation Type and Topic Source

Topic Source	Basic Research	Applied Research	Total	Proportion of Basic Research (%)	Average Study Duration (months)
National Natural Science Foundation of China (NSFC)	7	6	13	53.8%	67.5
National Key R&D Program/973/863 Program	0	7	7	0%	62.9
Others (non-funded, university-selected, etc.)	2	10	12	16.7%	53.3
Total	9	23	32	28.1%	60.9

Note: “Others” includes projects commissioned by enterprises or institutions, university-selected projects, unfunded projects, National Social Science Foundation projects, etc.

4. Discussion

4.1 Main Findings and Theoretical Dialogue

Firstly, an extension of screening theory: 'temporal imbalance' and 'institutional rigidity'. This study found that screening pressure was highly concentrated on the stage of publishing papers. At the same time, defense of proposals and mid-term evaluations were largely ineffective, exhibiting the characteristic of 'temporal imbalance'. After raising the graduation requirement from one SCI/EI paper to two, the graduation rate plummeted from 100% to 36.8% (p=0.002), reflecting 'loose coupling' within the institution — raising standards is easy, but adjusting academic duration and support systems simultaneously lags. Together, these two findings suggest that screening theory needs to develop a 'discipline-specific' temporal model and pay attention to the degree of coupling among different institutional elements, in order to avoid 'single-item advance' reforms.

Secondly, there is an enrichment of academic community theory in the form of 'organizational boundaries' and 'cognitive inertia'. The graduation rate of students supervised by off-campus supervisors with administrative roles is only 9.1%, and their graduation advantage is just 16.7% that of students supervised by on-campus supervisors without administrative roles (p=0.042). This suggests that supervisory effectiveness is affected by 'organizational boundaries' — the core function of the academic community — and that 'legitimate peripheral participation' depends on sustained, embedded interaction. On the other hand, the U-shaped relationship between prior discipline and training efficiency (the graduation rate of same-category students is 28.9% lower than that of cross-category students) indicates the presence of 'cognitive inertia' in disciplinary paradigm shifts. Those who switch completely adapt faster because their expectations are clear. Those who switch partially, however, face implicit interference from their original thinking patterns, which can lead to difficulties. These two analytical dimensions add to academic community theory: 'organizational boundaries' and 'cognitive inertia'.

Thirdly, there is a deeper exploration of student development theory, focusing on 'time investment' and 'differentiated support'. While the difference in graduation rates between designated and non-designated students is not significant (p=0.155), the average study duration of designated students (75.3 months) is significantly longer than that of non-designated students (55.3 months) (p=0.001). This validates the 'time investment' hypothesis, which states that academic socialization requires sustained time investment and that fragmented time cannot support intensive academic training. Additionally, the moderating effects of topic source and research direction suggest that student development theory needs to focus on the 'environment–individual interaction' level. For example, graduates supported by NSFC projects have an average study duration of 67.5 months, with basic research accounting for 53.8%. In contrast, the autonomous driving direction has a study duration of only 38.5 months. This indicates that different research-oriented topics require differentiated academic duration arrangements and development support rather than a 'one-size-fits-all' training standard.

4.2 Mechanism Coupling and Theoretical Contributions

The three-dimensional factors are mutually locked. Logistic regression shows that the framework explains approximately 38.6% of the variance in graduation status. Theoretical contributions include constructing a three-dimensional analytical framework, expanding the applicability of screening theory in doctoral education, and enriching the 'organizational boundary' perspective of academic community theory.

Institutional pressure is transmitted to individuals through the environment, and individuals' difficulties in turn reinforce the institution's rigid implementation logic. Specifically, high-level publication requirements force supervisors and the academic community to focus on helping students meet the standards rather than expanding their interdisciplinary horizons. The postponement of proposal defense further reduces the time available for students to participate in interdisciplinary activities. Insufficient support from the academic community (e.g., low supervisory effectiveness of off-campus supervisors and a lack of institutionalized interdisciplinary arrangements) leaves individuals without diverse methodological support when they encounter research bottlenecks. Due to dual work and study pressures, designated students have fragmented research time and find it harder to maintain sustained research investment. This leads to significantly longer study durations. Meanwhile, the 'one-size-fits-all' institutional design (applying the same graduation requirements to all students and research areas) fails to effectively address the needs of the heterogeneous student population. The 'middle-ground dilemma' of students in the same category, the long study cycles of designated students, and differences in study duration across research areas and topics are all typical manifestations of the mismatch between institution, environment, and individual.

4.3 Conclusion

Firstly, the program's overall training efficiency is relatively low. The overall graduation rate is 42.7%, graduates take an average of 60.9 months to complete their studies (nearly two years longer than the standard academic duration), and only 5.3% graduate on time. After raising the graduation requirements, the graduation rate fell from 100% to 36.8% ($p = 0.002$).

Secondly, differences in training efficiency are constrained by three factors. At the institutional level, there is insufficient alignment between graduation requirements and the standard academic duration, with long publication cycles directly causing delays. At the environmental level, the graduation rate for students supervised by off-campus supervisors in administrative roles is just 9.1%, and interdisciplinary training lacks mandatory institutional arrangements. At the individual level, the relevance of the prior discipline has a U-shaped effect ($p = 0.037$): the graduation rate of designated students (32.1%) is lower than that of non-designated students (48.9%), though this difference is not significant ($p = 0.155$). However, designated students have a significantly longer study duration ($p = 0.001$). Additionally, the topic source and research direction influence study duration: graduates supported by NSFC projects have the longest average study duration (67.5 months), while those in the autonomous driving field have the shortest (38.5 months).

Thirdly, these three factors are mutually interlocking, and optimization requires systematic coordination. University X was officially approved as a degree-awarding institution for doctoral degrees in 2024, and this study provides empirical evidence for this approval.

5. Recommendations and Research Prospects

5.1 Recommendations

Based on the empirical findings of the three-dimensional analytical framework of 'institution–environment–individual', this study proposes the following optimization recommendations:

Firstly, in terms of the institutional dimension, the design should be adjusted to alleviate the 'requirement–duration' tension. To address the problems of 'temporal imbalance' and 'institutional rigidity', the following recommendations are made: Adjust the standard academic duration from three years to four years, or establish a '3+1' flexible academic duration system. Explore the inclusion of high-level engineering practice, disciplinary competitions, patent conversions, etc., in the recognition of graduation achievements, to reduce over-reliance on journal publications.

- Establish an 'academic writing workshop', held twice per semester, where graduate doctoral students share their review experiences. For basic research projects (e.g., NSFC projects), provide more flexible mid-term evaluation mechanisms. For applied research projects (e.g., autonomous driving), explore 'university–enterprise collaboration' to accelerate the transformation of achievements. At the same time, a dynamic evaluation mechanism should be established for the training program. The Graduate School should conduct statistical analysis of graduates’ study duration and publication status every September, produce an annual training quality report, and initiate a training program revision process if the graduation rate falls below 40% for two consecutive years.

Secondly, in terms of the environmental dimension, the academic community's role should be strengthened to address deficiencies in organizational boundaries. To address low supervisory effectiveness among off-campus supervisors, a dual-supervisor system should be established, comprising an off-campus supervisor and an on-campus co-supervisor. The 'Measures for the Recruitment and Management of Off-campus Supervisors' should be revised, and off-campus supervisors should be required to attend at least two in-person group meetings per semester. Supervisory hours should be recorded in the training system (no less than 30 hours per year), and the workload of on-campus co-supervisors should be counted towards teaching performance. To address the issue of insufficient interdisciplinary training, doctoral students should be required to take at least one or two interdisciplinary courses. The Graduate School should publish a course list each semester, and students should submit a learning report before the mid-term evaluation.

Thirdly, in terms of the individual dimension, implement differentiated student guidance in order to respond to heterogeneous needs. To address the significantly longer study duration of designated students, allow them to apply for a 'flexible study plan' with a maximum study period of seven years, and require them to submit a research progress report each semester. To address the 'middle-ground dilemma' (the lowest graduation rate among students in the same category), require students in the same category to attend a 'disciplinary paradigm shift workshop' (8 class hours in total) in their first semester, with successful cross-category doctoral graduates serving as teaching assistants. Fresh graduates should be required to complete one literature review and present it at a group meeting in their first semester.

5.2 Research Limitations and Prospects

This study is based on a single case, so caution is required when generalizing its conclusions. It relies mainly on quantitative data, which provides limited insight into the deep motivations of doctoral students. The proposed optimization paths still need to be tested in practice. Future research could involve multi-case comparisons, qualitative studies, and longitudinal comparative studies. Tracking the first cohort of doctoral students after University X's official approval and conducting a longitudinal comparative study between the 'special demand program' and the 'regular doctoral program' would be particularly valuable.

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References

[1] Ministry of Education. 2024 Education Statistics — Number of Doctoral Graduates (Completed), Degrees Awarded, and Projected Graduates. (20 March 2026). http://www.moe.gov.cn/jyb_sjzl/moe_560/2024/quanguo/202603/t20260318_1431284.html.

[2] Ministry of Education. 2023 Education Statistics — Number of Doctoral Graduates (Completed), Degrees Awarded, and Projected Graduates. (20 January 2025). http://www.moe.gov.cn/jyb_sjzl/moe_560/2023/gedi/202501/t20250120_1176263.html.

[3] J. Skopek, M.; Triventi, H.-P.; Blossfeld. How do institutional factors shape PhD completion rates? An analysis of long-term changes in a European doctoral program. Studies in Higher Education, 2022, Vol. 47(2): 318-337.

[4] Xu Lan, Wei Qingyi. The Evolution, Characteristics and Trends in the Evaluation of Doctoral Education Quality: A Perspective Based on Governance Theory. Degrees and Postgraduate Education, 2023, (9): 85–93.

[5] Chris M Golde. Leaving the Ivory Tower: The Causes and Consequences of Departure from Doctoral Study. Work and Occupations, 2002, Vol. 29(2): 264-266.

[6] Li Haisheng. Analysis of Factors Affecting the Delay in Completion of Doctoral Studies in China: Based on a Questionnaire Survey of 42 Graduate Schools. Degrees and Postgraduate Education, 2012, (5): 9–15.

[7] Julian Friedrich, Anna Bareis, Moritz Bross, et al. "How is your thesis going?"-Ph.D. students' perspectives on mental health and stress in academia. PloS one, 2023, Vol. 18(7): e0288103.

[8] Levecque K, Anseel F, De Beuckelaer A, et al. Work organization and mental health problems in PhD students. Research Policy, 2017, 46(4): 868-879.

[9] Taylor Winter, Benjamin C Riordan, John A Hunter, et al. A Longitudinal Study of Mental Wellbeing in Students in Aotearoa New Zealand Who Transitioned Into PhD Study. Frontiers in psychology, 2021, Vol. 12: 659163.

[10] Bao Wei, Wu Jiaqi, He Feng. How to Optimally Determine the Scale of Doctoral

Student Intakes: An Analysis of the Correlation between Supervisor Supervision Load and the Quality of Doctoral Education. Chinese Higher Education Research, 2021, (4): 75–81.

[11]Wang Haiying, Li Haisheng, Chen Le. A Study on the Impact of Supervisory Guidance on the Quality of Doctoral Student Training. Journal of Yangzhou University (Higher Education Research Edition), 2023, 27(3): 72–81.

[12]Golde, Chris M. The Role of the Department and Discipline in Doctoral Student Attrition: Lessons from Four Departments. The Journal of Higher Education, 2005, Vol. 76(6): 669-700.

[13]Yang Qing, Tang Yuguang. A Study on the Stages of Professional Socialization, Obstacles and Deconstruction Strategies for Doctoral Students with Extended Study Periods. Research on Postgraduate Education, 2024, (5): 100-111.

[14]Xie Xin, Xu Dandong. The Impact of Interdisciplinary Thesis Research on Delayed Graduation among Doctoral Students: An Analysis Based on a National Survey of Doctoral Graduates. Chinese Higher Education Research, 2024, (6): 69–76.

[15]Sheng Lihui. The Phenomenon of Delayed Graduation among Doctoral Students: Influencing Factors and Governance Strategies. Degrees and Postgraduate Education, 2019, (6): 60–64.

[16]Xie Xin, Shen Wenqin. Types of Delayed Graduation among PhD Students and the Quality of Their Theses: An Analysis Based on Data from the 'National Survey of PhD Graduates'. Research on Higher Education, 2023, 44(9): 48–60.