An Analysis on the Difference of Research Competency of Engineering Doctoral Students with Various Characteristics Based on SPSS

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Abstract. Engineering and technical talents have become the "dancing partners" of AI and the "bodyguards" of big data security. As a reserve of high-level engineering and technical talents, the research competency of engineering doctoral students will affect the speed of technological innovation. The paper takes 163 engineering doctoral students from a research university in Liaoning as the research object, using SPSS to analyse the difference of research performance under various characteristics. ANOVA shows that significant differences exist in gender, undergraduate and master's degrees universities, interdisciplinary and admission type. Regression analysis shows that admission type affects the research performance of engineering doctoral students. The results provide a scientific basis for the cultivation of high-level innovative scientific and technological talents in engineering technology.

Keywords: Engineering and Technical Talents · Research Competency · Engineering Doctoral Students · SPSS

1 Introduction

In the era of knowledge economy, technological innovation has effectively promoted the progress of human civilization [4]. Talent is essential to scientific and technological innovation [5]. As the highest level of higher education, the education of engineering doctoral shoulders the heavy responsibility of cultivating high-quality and high-level creative talents for the country's modernization construction. In China, the size of doctoral students has been growing rapidly since the expansion of college enrolment in 1999. In 2020, The number of engineering doctoral students enrolled and in School is 116,000 and 466,600, about 10 times than 1997, of which the enrolment of students and students in school accounted for 41.27% and 41.98%, which has always been the largest.

While the number has increased, quality issues have gradually been the subject of attention by the government and universities [6]. The quality and quantity of engineering doctoral education can highlight education and technology in a country, while the essential factor is the research competency. Presently, doctoral students that only have diplomas and academic qualifications can't integrate with society [3]. They must have

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professional knowledge and research competency to meet universities, research institutes and enterprises [2]. Therefore, they need to continuously learn specialized theoretical knowledge, meanwhile, pay more attention to cultivating comprehensive research competency.

The paper analyzes the differences in engineering doctoral students of a university in Liaoning province on research competency. The paper takes research competency as a comprehensive competence formed by engineering doctoral students in the process of engaging in scientific research, which is reflected in performance of academic papers and programs [1].

The empirical result will provide an important basis for admission and improvement of engineering doctoral cultivation.

2 Method

2.1 Preparation for Questionnaire

The questionnaire consists of 65 questions, including four parts: personal information, research performance, research motivation and environmental support. The internal consistency test was done on 18 topics of research motivation and 24 topics of environment support, the α coefficients of Cronbach were 0.895 and 0.925. Due to the high consistency index, this measurement meets requirements.

Based on the existing literature and used scales, the questionnaire has good content validity after pre-investigation of small samples.

2.2 *Sources of Data*

The sample used in this study involved 163 engineering doctoral students in a research university of Liaoning. The details are shown in Table 1.

Table 1. Sample details

Personal information		N	Proportion (%)
Gender	Male	126	77.30
	Female	37	22.70
Age	20–30	127	77.91
	31–40	34	20.86
	Over 40	2	1.23
Bachelor	985	87	53.37
	211	54	33.13
	Non-211	22	13.50

(*continued*)

Table 1. (*continued*)

Personal information		N	Proportion (%)
Master	985	133	81.60
	211	29	17.79
	Non-211	1	0.61
Interdisciplinary	All	4	2.45
	Bachelor-Master	39	23.93
	Master- Ph.D.	4	2.45
	None	116	71.17
Worked	Yes	24	14.72
	No	139	85.28
Admission type	General	59	36.20
	Master-Ph.D.	80	49.08
	Nonstop	24	14.72

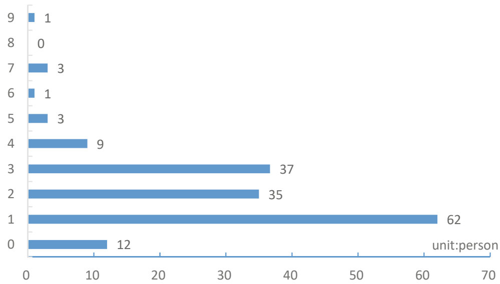

Fig. 1. Participation in academic programs

3 Results

3.1 Descriptive Statistics of Research Performance

3.1.1 Academic Program

a. Total number
According to the survey results, most individuals participated in the academic program, only 7.3% did not, the number of participants in 1–3 programs accounted for 82.2%, and only one participated in 9 programs. As shown in Fig. 1.

b. Academic program level
The Academic programs are divided into three levels (Table 2):
Grade I: Key/Major program of the National Natural Science Foundation of China or program with funds of over 1 million RMB;
Grade II: General program of the National Natural Science Foundation of China or program with funds of over 500,000 RMB;

Table 2. Statistics on the number of participating programs

Program Grade	Number of program	Number of participating	Percent (%)
I	0	69	42.33
	1	57	34.97
	2	34	20.86
	3	3	1.84
II	0	53	32.52
	1	69	42.33
	2	28	17.18
	3	12	7.36
	4	1	0.61
III	0	101	61.96
	1	44	26.99
	2	14	8.59
	3	3	1.84
	4	1	0.61
IV	0	127	77.91
	1	24	14.72
	2	3	1.84
	3	9	5.52

Grade III: Youth Program of National Natural Science Foundation of China or program with funds over 300,000 RMB;

Grade IV: Others.

c. Forms of participation

It shows that the majority are participating members of the research group, and only a few are sub-program leaders. In the Grade I, only one is the sub-program leader; the II, they are general members, and the III, three doctoral students are sub-program leaders, and the rest are general members; The IV, six are sub-program leaders, and the rest are general members. Therefore, a small number have the competency to independently undertake research program.

3.1.2 Academic Papers

The data shows that 288 papers were published in leader author, among which 7.29% were published in Q1, 50.35% in Q2, 20.14% in Q3 and 22.22% in Q4, with 1.8 papers per capita. 201 papers were published by co-second author, among which Q1 accounts for 12.15%, Q2 for 29.17%, Q3 for 14.24%, and Q4 for 14.24%, with 1.2 papers per capita. As shown in Fig. 2.

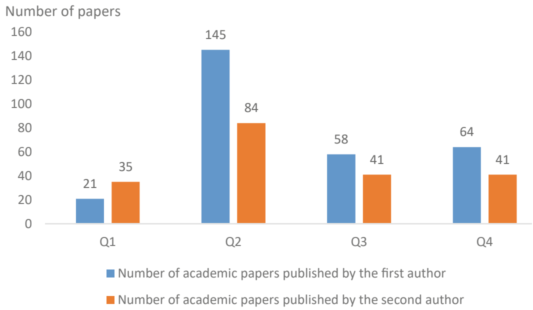

Fig. 2. Academic papers published by engineering doctoral students with leader or co-second author

3.1.3 Monograph and Patent

The survey results show that only 14 engineering doctoral students participate, accounting for 8.59%; 9 students compiles reference books, accounting for 5.52%; 22 students compiles textbooks, accounting for 13.49%, and none compiles them. A total of 22 patents are applied, including 4 patents applied by one person, 3 patents applied by one person, 1 patent applied by six people and one patent applied by nine students.

3.1.4 Scoring Strategy

Based on the literature review of research performance measures, it is common that directly apply quantity as evaluation index. This paper sets the scoring strategy for the research performance of engineering doctoral students as follows:

$$\delta = \sum (Q_i \times Y_i) + \sum (B_i \times G_i) + \sum (P_i \times M_i) \tag{1}$$

Note:
δ- Research performance scores for engineering doctoral students;
Q_i- Number of academic paper;
Y_i-Scoring the corresponding divisions of journals for academic paper;
B_i-Number of publications;
G_i- Score a monograph;
P_i- Number of patents applied;
M_i- Score patent.

Due to the different impact factors of different journals, the corresponding weights are set on the basis of journal partitions to replace the specific impact factors in this study as shown in Table 3.

Due to the small number of monographs and patents, the weight is set to 1 point per item.

According to the scoring strategy described above, the research performance score of doctoral students in engineering is obtained, it is shown in Fig. 3.

Table 3. Weight in different divisions

	Q 1	Q 2	Q 3	Q 4
Leader author	8	7	6	5
Co-second author	4	3	2	1

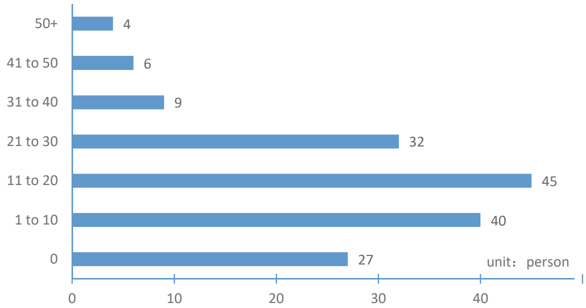

Fig. 3. Research Performance Scores

Table 4. Independent sample T test (Gender)

	Variance homogeneity test				T test of mean		
	F	Sig.	T	DF	Sig.	Diff.	SE
A	2.635	.106	2.120	161	.035	5.272	2.489
B			2.518	83.834	.015	5.272	2.095

(Notes: $p < 0.001$ means particularly significant; $p < 0.01$ means very significant; $p < 0.05$ means significant; *A means assumed the two are equal *B means assumed the two are not equal. The same below)

Table 5. Grouping data (Gender)

	Gender	N	M	SD	SE	M
Score	male	126	16.77	14.130	1.326	1.289
	female	37	11.51	10.054	1.652	1.631

3.2 Difference Analysis

3.2.1 Gender

The differences between sex and scores were analyzed by T test, and the results are shown in Table 4. The significance level of the variance homogeneity test is 0.106(>0.05), which is homogeneous. The mean T test value P is 0.035(<0.05), indicating that male

Table 6. Analysis of variance (Age)

	SS	DF	$Mean^2$	F	Sig.
Factor	262.172	2	131.086	.732	.485
Error	28965.760	160	181.036		
Total	29227.932	162			

Table 7. Descriptive statistics (Age)

	N	M	SD	SE	Min	Max
20–30	127	14.960	13.683	1.196	0	68
31–40	34	18.510	12.156	2.432	0	55
Over 40	2	14.200			14	16
Sum	163	15.510	13.432	1.075	0	68

and female engineering doctoral students have a significant difference in research performance. Judging from Table 5, the overall research performance score of male is higher than female.

3.2.2 Age

The average enrolment age of subjects was 26.78 years, and the difference in the scores of different ages was compared. The results of Table 6 show that the p is 0.485, it is greater than 0.05, indicating that the difference in scientific research performance of different ages is not significant. As is shown in Table 7, the number of samples over the age of 31 is quite different from the samples above 20–30 and the standard deviation is also large, so it is not appropriate to make a simple comparison between the two groups of age groups.

3.2.3 Undergraduate University

Most of the 163 engineering doctoral students involved studied in “985” universities, accounting for 53.37%, followed by “211” universities with 33.12%. Using ANOVA, as shown in Table 8, $p < 0.001$ means the scientific performance from different school is very various. The average value of the grouped data indicates that the scientific research performance of engineering doctoral students studying in ordinary universities is relatively low overall, and the maximum data reflects the scientific research performance of engineering doctoral students in individual general universities is higher than that of “985” and “211” universities. It is shown in Table 9.

Table 8. Variance analysis (Undergraduate)

	SS	DF	$Mean^2$	F	Sig.
Factor	6325.652	2	3162.826	22.186	.000
Error	22813.760	160	142.586		
Total	29139.412	162			

Table 9. Descriptive statistics (Undergraduate)

	N	M	SD	SE	Min	Max
Non-211	22	4.56	10.779	2.420	0	48
211	54	10.68	8.862	1.226	0	28
985	87	22.06	13.721	1.497	0	68
Sum	163	15.52	13.467	1.078	0	68

Table 10. Variance analysis (Master's University)

	SS	DF	$Mean^2$	F	Sig.
Factor	5311.916	2	2655.958	17.786	.000
Error	23396.160	160	146.226		
Total	28708.076	162			

3.2.4 Master's Degree University

At present, the admission of doctoral students in China generally adopts the "application-assessment" system, and the candidates whose master's degree institutions are "985" are more likely to be obtained. Analysis of variance (ANOVA) is found to be $p < 0.001$, indicating that the scientific performance from different master's school is significantly different. It is shown in Table 10. The scores in "985" master's colleges are significantly higher than those of "211" and ordinary students. Due to the large difference in different groups, the sample number of ordinary universities is only 1, which cannot explain the scientific research performance of doctoral students in this category. It is shown in Table 11.

3.2.5 Interdisciplinary Situation

The interdisciplinary situation of subjects involved was divided into four categories: all, Bachelor-Master, Master- Ph.D. and None. Through the analysis of variance, the $p < 0.001$ is obtained, indicating that the difference is very significant. It is shown in Table 12. The average scores of engineering doctoral students who have none are significantly higher than those who have interdisciplinary situation, the scores of engineering doctoral

Table 11. Descriptive statistics (Master's University)

	N	M	SD	SE	Min	Max
Non-211	1	.00			0	15
211	29	3.55	5.088	.962	0	20
985	133	18.33	13.532	1.175	0	68
Sum	163	15.52	13.476	1.078	0	68

Table 12. Variance analysis (Interdisciplinary)

	SS	DF	$Mean^2$	F	Sig.
Factor	4036.053	3	1345.351	8.486	.000
Error	25211.676	159	158.564		
Total	29247.729	162			

Table 13. Descriptive statistics (Interdisciplinary)

	N	M	SD	SE	Min	Max
All	4	6.43	5.687	3.284	0	11
Bachelor-master	39	8.39	8.204	1.332	0	28
Master-doctoral	4	.00	.000	.000	0	0
None	116	18.63	13.946	1.316	0	68

students who have Bachelor-Master are higher than the average of engineering doctoral students who have Master-Ph.D., indicating that the professional foundation has a greater impact on the performance. It is shown in Table 13.

3.2.6 Work Experience

The 163 students, 85.28% have no work experience. Using the independent sample T test, the p-value was 0.146, which is greater than 0.05, and the t-test result is p-value of 0.802, which is greater than 0.05, indicating no significant difference exists between whether they have work experience and the scientific research performance. It is shown in Table 14. The average value of the two is not much different, indicating that work experience has no impact on the scientific research performance. It is shown in Table 15.

Table 14. Independent sample T test (Work Experience)

	Variance homogeneity test				T test of mean		
	F	Sig.	F	Sig.	F	Sig.	F
A	2.111	.146	−.253	161	.802	−.787	3.108
B			−.317	35.687	.753	−.787	2.472

Table 15. Grouping data (Work Experience)

	Worked	N	M	SD	SEM
Score	none	139	15.65	13.978	1.207
	have	24	16.15	10.113	2.157

Table 16. Variance analysis (Admission Type)

	SS	DF	$Mean^2$	F	Sig.
Factor	2505.537	2	1257.269	7.474	.001
Error	26969.120	160	168.557		
Total	29474.657	162			

Table 17. Descriptive statistics (Admission Type)

	N	M	SD	SE	Min	Max
General	59	13.64	12.524	1.668	0	68
Master-Ph.D.	80	13.88	13.895	1.623	0	58
Nonstop	24	23.68	11.428	2.123	0	45
Sum	163	15.51	13.475	1.078	0	68

3.2.7 Admission Type

Admission type is divided into three categories: General, Master-Ph.D., Nonstop. Using ANOVA, the p value is 0.001, which is less than 0.01, indicating that performance of engineering doctoral students in different admission methods is very different. It is shown in Table 16. The average score of Nonstop is higher than other, indicating that research performance of Nonstop is higher than that of General and Master-Ph.D. It is shown in Table 17.

Table 18. Regression coefficients

	Unstandardized coefficient		Standardized coefficients		Sig.
	B	SE	Regression coefficient	T	
Constant	−1.415	9.775		−.146	.773
Gender	1.198	1.658	.043	.789	.427
Bachelor	2.249	1.316	.116	1.720	.083
Master	1.577	2.363	.049	.695	.462
Interdisciplinary	1.097	.765	.064	1.362	.159
Worked	−2.734	2.582	−.073	−1.068	.272
Age	.892	2.468	.027	.354	.709
Admission Type	2.608	1.179	.137	2.165	.033

3.3 Regression Analysis

The dependent variable is the research performance, and the independent variable is 7 student-derived characteristic variables. Through regression analysis, the model goodness of fit is 0.685, indicating that the model fit effect is better, which could explain the 68.5% variation in the performance score. Analysis of variance on the regression model, with a p-value of less than 0.001, indicating that the regression model is significant. The regression coefficient between them is shown in Table 18, and the p-value of the available admission type is less than 0.05, indicating that the linear relationship is significant. It is shown in Table 18.

4 Conclusion

According to the results, significant differences in the research level of engineering doctoral students of different genders, undergraduate university and master's degrees university, interdisciplinary and admission type are obvious, but the other is small. Based on results, admission type affects the research performance, and the continuous study has better performance than intermittent learning.

5 Discussion

Doctoral education shoulders heavy responsibility for cultivating, which should be strengthened today. Enrolment is the first link in the admission, whether doctoral students with research competency can be admit directly affects the quality and efficiency. As Mr. Pan Mao Yuan said: "Recruiting talents is like sowing seeds by farmers, the quality of the seeds directly affects the harvest, and the quality of the admission of talents directly affects the quality of doctoral students." Awarding unit should formulate the admission criteria for engineering doctoral students, paying attention to the investigation of the comprehensive quality of engineering doctoral students, evaluating their knowledge base, research competency, innovation competency, academic interest, moral quality, etc. Then engineering doctors with research competency are prominent. Therefore, in "application-assessment" system, we must rethink the evaluation of the scientific research competence of engineering doctoral students, and then clarify the admission criteria for them, which is of great significance for improving the quality.

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