



A Statistical Framework for Evaluation of Graduate Student Leadership Training Based on Entropy Method in the Context of New Engineering

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Abstract. Economic development and education have placed new demands on graduate education, especially leadership training. China proposes that universities should accelerate the construction and development of new engineering disciplines. In order to solve the above problems, this study conducted a questionnaire survey on 1680 graduate students using self-designed questionnaires. And a statistical analysis framework containing regression analysis, descriptive analysis and entropy method is provided. The results of the study showed that organizational communication skills (0.545) and career planning skills (0.524) significantly influenced students' leadership. In addition, the results of the entropy method of analysis showed that the public service activities or volunteer activities that students had participated in were also extremely important in influencing their leadership. The study in this paper provides an empirical analysis of student leadership development in the context of the new engineering discipline, which has important implications for teaching policy development and teaching evaluation in higher education institutions.

Keywords: statistical analysis · regression · entropy method · leadership development

1 Introduction

Engineering education occupies an important position in China's higher education. High-quality engineering science and technology talents are an important guarantee for supporting industrial transformation and upgrading and implementing national major development strategies. At present, a new round of scientific and technological revolution and industrial change is accelerating worldwide. At present, a new round of scientific and technological revolution and industrial change is accelerated worldwide. The new economy characterized by new technology, new business mode, new industry and new mode is developing vigorously, which urgently needs to cultivate and create a large number of diversified and innovative engineering science and technology talents. China took the lead in putting forward the concept of "new engineering" in the field of higher education,

and reached the “Fudan Consensus” on the construction of new engineering in 2017, proposing that our universities should accelerate the construction and development of new engineering, and later put forward the “After that, the “Tianda Action” and “Beijing Guide” were proposed to explore the Chinese model and experience of leading the global engineering education and help the construction of a strong country of higher education. The development of new engineering will effectively promote the deep integration of higher education and social production of enterprises, thus promoting the long-term development of China’s economy and society. Colleges and universities should take the initiative to serve the national strategic needs and the needs of industries and enterprises, accelerate the construction and development of new engineering disciplines, explore the formation of engineering education system with Chinese characteristics and world level, and promote China from a large engineering education country to a strong engineering education country.

New engineering is closely related to strategic emerging industries. Strategic emerging industries are knowledge- and technology-intensive industries with low consumption of material resources, high growth potential and good overall benefits based on major technological breakthroughs and major development needs, which have significant leading and driving effects on the overall and long-term development of the economy and society [1]. National strategic emerging industries need a large number of senior talents as support, and it is an important task of higher education to cultivate high-quality talents who can go in the same direction with national strategy and regional development. General Secretary Xi Jinping pointed out that for the new situation of China’s economic development, the development of human resources should be given the highest priority in science and technology innovation, and the mechanism of training, introducing and using talents should be reformed, and efforts should be made to create a number of world-class scientists, leading scientists and engineers, as well as high-level innovation teams, with emphasis on training young scientific and technological talents and front-line innovators.

The new engineering emphasizes actively responding to changes, actively shaping the world, and promoting the overall improvement of talent cultivation quality. Society’s demand for talents will be characterized by high volume, high level, specialization and diversity. General Secretary Xi Jinping emphasized that graduate education has an important role in cultivating innovative talents, improving innovation ability, serving economic and social development, and promoting the modernization of national governance system and governance capacity. Postgraduate education is the top of national education, but also the driving force of national innovation system, assuming the dual mission of “scientific and technological innovation” and “high-end talent supply”, becoming an important reserve of talents needed for economic development, and providing important technical support and intellectual foundation for economic development. The cultivation of graduate students with leadership ability is an important demand in the context of new engineering.

The rest of this paper is organized as follows: Sect. 2 provides a detailed discussion of the methodology of this paper. The obtained results are discussed in Sect. 3. Finally, Sect. 4 summarizes the full paper and suggests future research directions.

2 Materials and Methods

2.1 Entropy Method

In general, evaluation criteria can be categorized into two types: benefit criteria and cost criteria. Benefit criterion means that a bigger value is more valuable whereas cost criteria are just the opposite. In the following section, we will describe the entropy method in detail.

Step 1: Normalization. Since the measurement units of the indicators are not uniform, they are standardized before using them to calculate the composite indicators, i.e., the absolute values of the indicators are converted into relative values and ordered, thus solving the problem of homogenization of the values of the different qualitative indicators. Moreover, since the positive and negative indicators represent different meanings (the higher the value of positive indicators is, the lower the value of negative indicators is), we use different algorithms to standardize the data for high and low indicators. The specific method is as follows:

$$x'_{ij} = \frac{x_{ij} - \min\{x_{1j}, \dots, x_{nj}\}}{\max\{x_{1j}, \dots, x_{nj}\} - \min\{x_{1j}, \dots, x_{nj}\}} \quad (1)$$

$$x'_{ij} = \frac{\max\{x_{1j}, \dots, x_{nj}\} - x_{ij}}{\max\{x_{1j}, \dots, x_{nj}\} - \min\{x_{1j}, \dots, x_{nj}\}} \quad (2)$$

where x'_{ij} is the normalized indicator.

Step 2: Computing weights. In this step, we use the Eq. (3) to compute the weights of indicator x_{ij} .

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad (3)$$

where $i = 1, 2, \dots, n$, $j = 1, 2, \dots, m$.

Step 3: Computing the entropy value using Eq. (4):

$$e_j = -k \sum_{i=1}^n p_{ij} \ln(p_{ij}) \quad (4)$$

where $k = 1 / \ln(n) > 0$ and $e_j \geq 0$.

Step 4: Computing the entropy redundancy:

$$d_j = 1 - e_j \quad (5)$$

Step 5: Computing the weights:

$$w_j = \frac{d_j}{\sum_{j=1}^m d_j} \quad (6)$$

Step 6: Computing the score:

$$s_i = \sum_{j=1}^m w_j p_{ij} \quad (7)$$

In what follows, we will use the entropy method to calculate the weights of each indicator.

2.2 Data

In order to conduct a questionnaire survey on the current situation of leadership literacy and school study of engineering graduate students, a total of 1800 questionnaires were distributed to graduate students, and 1680 valid questionnaires were recovered, with a recovery rate of 93.33%. The age of the survey respondents was 21–35 years old, with an average of 24.23 years old; 1025 were male students and 655 were female students. The survey results were analyzed by SPSS 17.0.

The obtained data can be summarized as follows (Table 1)

Furthermore, we show the ratio of answers in Fig. 1.

Table 1. The description of obtained dataset

Indicator	Symbol
Participated in leadership training	X1
Participated in leadership literacy training during your graduate study	X2
Served as monitor or Party branch secretary and other positions	X3
Participated in any student associations	X4
Participated in public welfare activities or volunteer activities	X5
Participated in relevant science and technology competitions and acted as team leader	X6

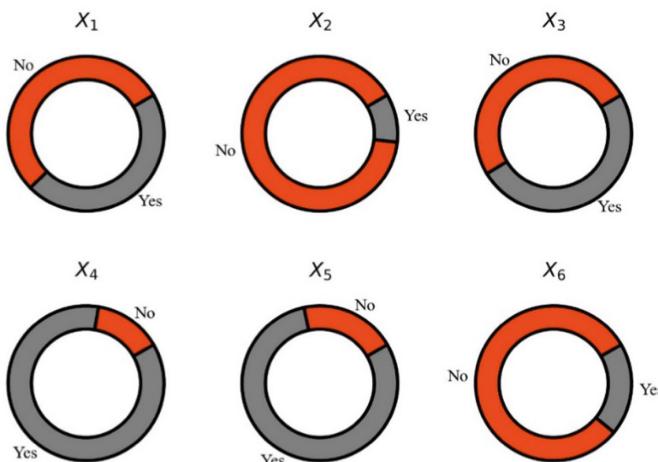


Fig. 1. The ratio of each answer.

3 Results and Discussions

3.1 Graduate Student Leadership Profile

Among 1680 postgraduates, the number of those who had leadership literacy-related training experience was 773, accounting for 46.01%; among them, only 170, accounting for 10.12%, had obtained relevant training experience during postgraduate study.

The number of postgraduates who had leadership experience such as class president or party branch secretary was 835, accounting for 49.70%; 1,443 postgraduates had participated in various student organizations, accounting for 85.89%; 1,345 postgraduates had participated in various public welfare practice activities or volunteer activities, accounting for 80.06%; only 324 postgraduates had participated in various science and technology competitions and served as team leaders, accounting for 19.29%.

This indicates that graduate students are more involved in the practical experience of leadership literacy, but they have not received enough training.

3.2 The Department of Emotional Intelligence Leadership for Graduate Students

The emotional intellectual leadership of doctoral students ($M = 92$ out of 120) is significantly higher than the emotional intellectual leadership of master students ($M = 89$); the emotional intellectual leadership of female students ($M = 91$) is significantly higher than the emotional intellectual leadership of male students ($M = 88$); the emotional intellectual leadership of graduate students who have participated in leadership literacy related training ($M = 91$) is significantly higher than the emotional intellectual leadership of graduate students who have not participated in related training ($M = 89$).

3.3 Practical Behavioral Leadership of Graduate Students

No significant difference was found between the practical behavior leadership of doctoral students ($M = 117$ out of 150) and master students ($M = 116$); the practical behavior leadership of female students ($M = 117$) was significantly higher than that of male students ($M = 112$); the practical behavior leadership of graduate students who had participated in various practical activities ($M = 119$) was significantly higher than that of graduate students who had no relevant experience ($M = 113$).

3.4 The Relationship Between Graduate Student Leadership and Various Factors

Leadership of graduate students was positively related to organizational communication ability, innovation and practice ability, cultural transmission ability and career planning ability. Among them, leadership had the highest correlation with organizational interaction ability ($r = 0.545$), followed by career planning ability ($r = 0.524$), and the correlation with innovative practice ability and cultural transmission ability were 0.394 and 0.242.

Based on the correlation analysis, a model was constructed to explore whether each quality competency would have a predictive effect on leadership. The results of the regression analysis showed that organizational interaction ability, innovative practice ability,

Table 2. Correlation analysis of leadership and each competency score

	Organizational interaction ability	Innovative practice ability	Cultural transmission ability	Career planning ability
Leadership	0.545**	0.394*	0.242*	0.524**

Note: * represents significant correlation, ** represents very significant correlation

Table 3. Regression analysis between leadership and each competency

	Regression Coefficient	Standardized regression coefficients	Significance
Organizational interaction ability	0.266	0.294	P < 0.001
Innovative practice ability	0.117	0.105	P < 0.001
Cultural transmission ability	0.011	0.011	P = 0.055
Career planning ability	0.258	0.263	P < 0.001

Table 4. The mean value of the obtained data

Indicator	Mean value (percentage)
X1	46.01
X2	10.11
X3	49.70
X4	85.89
X5	80.05
X6	19.28

and career planning ability all had significant effects on graduate student leadership, except for cultural transmission ability, which was relatively weak (Tables 2 and 3).

3.5 The Results of Entropy Method

We first define the “Yes” answer to 1, and “No” answer to 0. Then, we can get the mean value of each indicator, as shown in Table 4.

Then, based on the above mentioned entropy method, we can get the weight of each indicator as:

Thus, from Table 5 we can see the X5 is the most weighted indicator among the above six indicators. It shows that students participated in public welfare activities or volunteer activities has the most important impact on their leadership.

Table 5. The weight of each indicator

Indicator	Weight
X1	0.12
X2	0.06
X3	0.13
X4	0.24
X5	0.31
X6	0.14

4 Conclusion

Traditionally, leadership education is about three levels: firstly, knowing people well, how to do the right things with the right people; secondly, leading teams, shaping the chemistry of diverse teams; thirdly, change and transformation, promoting the continuous change and development of the organization. However, these three levels focus more on the behavioral level, but not much on the thinking and strategic level. Change is the eternal theme of economic and social development. In recent years, technological development is rapidly changing our lives, which is an era of co-creation, sharing and sharing. This era has seen disruptive changes, cross-border competition and integration, borderless organization, asset-light entrepreneurship, from industry breeding talent to talent-led industry, etc. These phenomena require us to reflect, improve and upgrade at the thinking level. Sun Chunlan, a member of the Political Bureau of the CPC Central Committee and Vice Premier of the State Council, pointed out at the National Conference on Graduate Education that research should be taken as the basic index to measure the quality of graduate students, optimize the layout of disciplines and specialties, focus on classification and cultivation, openness and cooperation, and cultivate high-level talents with research and innovation ability [3]. Graduate education is the main way to cultivate high-level innovative talents, the basic layout to cope with global talent competition, and an important cornerstone to implement innovation-driven development strategy and build an innovative country. Under the background of new engineering, we must unswervingly push forward the reform, gather and create excellent talents with global competitiveness, and form a new “high-end talent dividend”; produce more and better scientific research results, so that innovation can become the endogenous driving force and leading force for driving development; for cultivating leadership, organizational communication, innovation and practice ability and cultural heritage and innovation ability of engineering graduate students. Thus, we further propose the following suggestions.

4.1 Organizational and Interaction Skills

In the context of new engineering, graduate students with leadership skills, as team leaders, need to have good interpersonal skills, organizational and coordination skills, communication skills and the ability to solve complex problems. In the process of listening and interacting, they are good at getting others' wisdom and seeing things from

multiple perspectives; in the process of expressing thoughts and emotions accurately, they can organize language to infect others.

Universities should give full play to the role of self-education, self-management and self-innovation of graduate student organizations. In addition to graduate student associations and graduate student societies, there are also student chapters of academic societies, such as IEEE student chapter, Chinese Computer Federation (CCF) student chapter, Chinese Institute of Electronics student workstation, Optical Society of America (OSA) student chapter, International Society of Optics (SPIE) student chapter, etc. Discover and carry out various postgraduate scientific and technological cultural activities, vigorously advocate the cultivation of student leadership, stimulate the potential leadership of postgraduates, let them highlight their own advantages in scientific research and work, and maximize the embodiment of personal leadership. Through the communication and sharing series of activities, we aim to build a bridge for all postgraduates to self-communicate, communicate and promote each other, enhance the organizational interaction and expression ability of postgraduates, and jointly promote the improvement of postgraduate training quality. Strengthen the efforts of postgraduate social practice. On the basis of the existing science and technology to the countryside, supporting agriculture and teaching, new rural construction, expand the platforms such as science and technology attachment, enterprise practice training base, joint training base, etc., open up the channel of attachment to government agencies, and increase the coverage of postgraduate social practice.

Universities can implement training programs for postgraduate cadres, mainly for postgraduate party branch secretaries, cadres of postgraduate associations at school and college levels, cadres of postgraduate academic organizations at school level and main leaders of postgraduate associations at school level. Through serving as student cadres, postgraduates can improve their problem-solving ability, teamwork, stress tolerance and frustration resistance, as well as their sense of responsibility to serve others and society [4]. Through the “Comprehensive Leadership Development Series”, “Special Ability Enhancement Series”, “Independent Communication and Interactive Sharing Sessions”, and “Practical Development Sessions”, we have been able to provide students with the opportunity to develop their leadership skills. The university can improve the comprehensive quality of postgraduate cadres and give full play to their pioneering role, so as to build up a cadre of postgraduates with both moral and talent and broad-mindedness, and cultivate excellent management talents with high education for the society.

Colleges and universities can also strengthen international exchanges and expand the horizons of graduate students. Hold summer schools and invite foreign experts to give intensive lectures to graduate students to enhance their ability to solve complex problems; hold cultural exchange summer camps so that graduate students can continuously improve their interpersonal and communication skills in the process of communicating with teachers and students of foreign universities.

4.2 Innovation Practice Ability

The world has entered the era of innovation, and the competition for innovation and talent has become more and more intense. Innovation has become a new playing field

for great powers to compete, and whoever dominates innovation will dominate the rules of the playing field and the course of the competition. Under the background of new engineering, it is impossible to have innovation, science and technology as well as industrial advantages without talent advantages, and postgraduate education, as the best combination of science and technology and education, is the main way to cultivate top innovative talents. Graduate education has the natural advantage of high convergence of innovative elements, and to better play the important role of graduate education for knowledge discovery and scientific and technological innovation, it is necessary to vigorously improve the innovation and practice ability of graduate students, which is an important component of the leadership of graduate students.

Colleges and universities should increase support for innovation and entrepreneurship of graduate students. In addition to the existing pyramidal innovation and entrepreneurship education system of universal education, practical education and incubation education constructed by universities, it is also necessary to establish a diversified academic registration management system to stimulate graduate students' innovation and entrepreneurship, and strengthen theoretical research and curriculum construction of innovation and entrepreneurship [5, 6]. A series of innovation and entrepreneurship funds should also be established jointly with government, industry, and alumni. It is also necessary to provide the entrepreneurial team with the full range of services such as mentorship, technology, legal and investment and financing negotiation. In this way, graduate students dare to innovate and start their own business to gain valuable assets in their life experience.

Universities can also organize and guide graduate students to participate in various forms of scientific and technological innovation activities and innovation and entrepreneurship competitions at home and abroad. Through the events, the bridge of close cooperation between universities, industries, enterprises and governments is built to create a platform for promoting collaborative innovation between government, industry, academia, research and application. Cultivate the innovation spirit, entrepreneurial consciousness and innovation and entrepreneurial ability of postgraduates, and stimulate their creativity [7].

4.3 The Ability of Cultural Heritage and Innovation

Under the background of new engineering, graduate students need to have the vision of cross-cultural dialogue and integrate the strengths of world civilization in order to contribute to the dissemination of Chinese culture and promote humanistic exchanges. To be able to read a lot to learn from the strengths of previous generations, to broaden the horizons of the past and the present, and to supplement the humanities knowledge in time. In the process of recording and memory playback, the ability to organize the memory of one's brain in an organized manner and sort out new ideas from a thousand things is an indispensable element of graduate student leadership.

Tapping the role of excellent Chinese traditional culture for postgraduate education. The report of the 19th National Congress points out that we should promote the creative transformation and innovative development of the excellent Chinese traditional culture. Excellent Chinese traditional culture is the deepest cultural gene, spiritual bond, and value source of socialist core values [8]. The cultivation of leadership requires not only

a solid professional foundation, but also a correct world view, outlook on life as well as values, and the formation of the ability to analyze and solve problems. The traditional culture about moral level and patriotism has a positive effect on the education of graduate students in scientific ethics, core values, ideals and beliefs.

Tapping the role of cultural confidence in leading postgraduates. Universities should focus on exploring the educational resources in Party history, university history and modern history, and strengthen the construction of network culture and campus culture to attract young people, so that postgraduates can gain a deeper understanding of the great journey of the Party leading the nation from national salvation to national rejuvenation, and thus gain the spiritual power to constantly seek progress and innovation and change.

4.4 Career Planning Education

Under the background of new engineering, colleges and universities must establish the sense of crisis of winning and losing and the awareness of market competition. The report of the 19th National Congress points out that employment is the biggest livelihood of the people, and we should adhere to the employment priority strategy and active employment policy to achieve higher quality and fuller employment. Colleges and universities should take the initiative to dovetail with industry and industrial needs, and take the initiative and make a difference in optimizing and adjusting the talent training structure, strengthening career guidance and innovation and entrepreneurship education. The final landing of leading talents is realized through employment. Therefore, the employment destination of graduate students plays an extremely important role in whether the graduate students trained by the school can become leading talents in various industries and play their leadership role.

Colleges and universities can implement phased career planning education for graduate students and set up phased goals and measures accordingly. Career planning education can effectively promote the improvement of graduate students' leadership [9]. In the adaptation stage: establish career goals, firm ideals and beliefs, and develop career interests. In the development stage: make a career plan, be creative and innovative, develop excellent skills, and prepare for career. In the selection stage: adjust career cognition, aspire to hard work, refine noble character, and establish career choice.

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