Applied Mathematics and Nonlinear Sciences

<https://www.sciendo.com>

College students' innovation and entrepreneurship ability based on nonlinear model

Xue Zhang^{1†}, Siyu Meng², Aiiad A. Albeshri³, Marwan Aouad⁴

¹College of Business Administration, Liaoning Technical University

²College of Business Administration, Liaoning Technical University

³Department of Computer Science, Faculty of Computing and IT,
King Abdulaziz University, Jeddah, Saudi Arabia

⁴Applied Science University, Al Eker, Kingdom of Bahrain

Submission Info

Communicated by Juan Luis García Guirao

Received June 16th 2021

Accepted September 24th 2021

Available online December 15th 2021

Abstract

The article analyzes why colleges and universities should strengthen innovation and entrepreneurship education based on “mass entrepreneurship and innovation” First, we conduct a questionnaire survey on the status of college students' innovation and entrepreneurship attitude and use nonlinear methods to construct an evaluation model of innovation and entrepreneurship capabilities to evaluate students' innovation and entrepreneurship capabilities quantitatively. Finally, we verify the effectiveness of the combined evaluation model through data on the innovation and entrepreneurship activities of college students. The research results can provide a new idea for appraisal of college students' innovation and entrepreneurship ability.

Keywords: nonlinear model, analytic hierarchy process, colleges and universities, innovation and entrepreneurship ability evaluation.
AMS 2010 codes: 34A34

1 Introduction

Since the entrepreneurial ability of college students is an extension of the entrepreneurial ability among college students, some factors that affect entrepreneurial ability will also affect the development of college students' entrepreneurial ability. Some scholars believe that an individual's entrepreneurial behavior, entrepreneurial cognition, and entrepreneurial environment constitute a dynamic and interactive relationship, which affects the generation and development of their entrepreneurial ability. Because of the uniqueness of college students, some exceptional factors affect the development of college students' entrepreneurial ability [1]. These factors

[†]Corresponding author.

Email address: zhangxue@Intu.edu.cn

are multifaceted. Some scholars believe that the influencing factors of college students' self-employment ability mainly include five aspects: skill level, motivation level, entrepreneurial ability level, environment level, and family level. Some scholars believe that the factors that affect the entrepreneurial ability of higher vocational graduates include internal factors such as the quality of college students and external factors such as the macroeconomic environment and family social conditions. Among many factors, the entrepreneurial education of college students has a crucial influence on the development of college students' entrepreneurial ability. Some scholars, based on empirical research in the United States, Asia, and Europe, have found that the practical realization of entrepreneurship education in colleges and universities depends on the the active and extensive participation of various stakeholders in society [2]. A robust internal organization promotes entrepreneurship education ; promotes the establishment of technology parks, incubators, technology transfer offices, etc; recruits entrepreneurial teachers to promote changes in education models; formulates corresponding incentive measures for entrepreneurial research, publishing, and teaching; ensures that the concept of entrepreneurship is embedded in the disciplines and comprehensive courses of each department; and encourages a wide range of interdisciplinary activities. Based on the university–industry–government triple-helix theory, some scholars have explored measures to strengthen students' entrepreneurial ability in entrepreneurial universities from the aspects of university self-construction, government, and industry. Some scholars believe that entrepreneurship education content should permeate into classroom teaching, entrepreneurship education activities should be reflected in the classrooms, and the results of entrepreneurship education should be implemented in social practice [3]. Some scholars believe that innovative experiments have a tremendously positive effect on cultivating college students' entrepreneurial ability.

Many domestic scholars have conducted few targeted studies on the factors influencing college students' entrepreneurial ability, but they have touched on this issue more or less from different aspects. However, these studies are relatively lacking in system and generality. Scholars at home and abroad have made active explorations on the model of entrepreneurial ability, and many of them have studied the model of college students' entrepreneurial ability. But there is no mature theoretical result that is widely recognized [4]. Due to the broad and narrow divergence levels in understanding college students' entrepreneurial ability, there are inevitably differences in the models constructed based on this understanding. In the above research results, some scholars have summarized the empirical research of predecessors through literature analysis and concluded that entrepreneurial ability has the following six capabilities: opportunity recognition, interpersonal relationship, concept, organization, strategy, and commitment. Some scholars have further expanded the entrepreneurial competency model. Its composition includes eight dimensions: opportunity ability, organizational ability, relationship ability, strategic ability, commitment ability, conceptual ability, emotional ability, and learning ability. Some scholars have constructed an entrepreneurial competence model framework based on foreign scholars' research on entrepreneurial competence models, which also includes narrowly defined entrepreneurial competence and business and management competence, interpersonal competence, and conceptual and relationship competence. Finally, some scholars used the competency model to divide the 20 influencing factors into five factors to construct an index model of college students' entrepreneurial ability. There are five dimensions: leadership communication, autonomous learning, frustration resistance, emotional control, and decision-making influence [5]. Among them, the influence of leadership communication on entrepreneurial ability is significantly more substantial than that of the other four abilities. This shows that an entrepreneur requires high leadership communication skills on the one hand. On the other hand, it also requires a relatively balanced emotion control ability, frustration resistance ability, independent learning ability, and decision-making influence.

Disciplinary competition in colleges and universities is one of the virtual channels and methods to implement the quality construction requirements of colleges and universities, cultivate innovative talents, and improve the awareness of innovation. This research on the evaluation of college students' creative ability belongs to the problem of multiattribute complexity. Some scholars use the analytic hierarchy process (AHP) and MFCE method to evaluate innovation and entrepreneurship and implement opinions comprehensively. On the other hand, some scholars have used the fuzzy AHP (FAHP) method to develop an index system and fuzzy compre-

hensive evaluation for the entrepreneurial ability of science and engineering college students.

Some scholars use the AHP of expert opinions to determine the importance of the evaluation index of college students' innovation ability. However, weight is an essential indicator of evaluation research, and a single method to determine attribute weight will inevitably lead to a one-sided evaluation. Therefore, this paper proposes to analyze the multiple complex factors that are interrelated and that restrict each other in the innovation ability evaluation system using the AHP and the coefficient of variation method. At the same time, we build an independent basic weight set. On this basis, we use the game theory to analyze its internal competition relationship and obtain the optimal comprehensive weight of the index. This provides a theoretical basis for the educational evaluation and decision-making of college students' innovative abilities.

2 Constructing an evaluation index system for innovation ability

There are many factors involved in the evaluation of college students' innovative ability cultivation in subject competitions. This article focuses on accumulating data using questionnaire surveys for the evaluation of students who participated in subject competitions within 2 years of graduation, as well as at the university [6]. We decompose the content of the questionnaire into target level, criterion level, and index level, with innovation capability as the evaluation objective. All indicators of the layered three-dimensional structure evaluation system are evaluated on a 10-point system. Table 1 shows the established evaluation index system for the innovation ability of discipline competitions.

Table 1 Evaluation index system

Target layer	Innovation ability A0			
Criterion layer	Creative thinking ability A1	Innovation ability A2	Scientific and technological innovation achievement A3	Innovative education benefit A4
Index layer	Logic analysis ability B11	Practical ability B21	Paper Publication B31	Scholarship B41
	Knowledge integration ability B12	Teamwork ability B22	Project Participation B32	Self-employment B42
	Question the ability to find problems B13	Communication and coordination ability B23	Technical works B33	Continue to study B43
	Abstract thinking ability B14	Writing ability B24	Science and technology project B34	
	Problem-solving ability B15			

3 Evaluation method

3.1 AHP to determine the subjective weight

The AHP divides the various evaluation factors into order. This method compares the relative importance of each level of factors, and at the same time, sorts the impact of indicators according to the weight value [7]. The specific steps are as follows.

(1) We select the average value of the evaluation index as the relative scale for pairwise cross comparison and construct the judgment matrix of each layer.

Taking the index layer as an example to construct the judgment matrix, we set the mean value of index i as V_i and the mean value of index j as V_j . If $V_i < V_j$, it means that index j is more critical than index i . When the difference is <0.1 , the scale is “2”; when the difference is $0.1-0.5$, the scale is “3”. Based on this recursion, we build a hierarchy relationship scale table with 2–9 scales (Table 2) and then use the evaluation scale comparison table to obtain the judgment matrix value a_{ij} . The criterion layer constructs the judgment matrix as the index layer. See Table 3 for the hierarchical relationship evaluation scale of scales 2–9. We take the criterion layer A1–A4 and the index layer B11–B15 as examples to construct the judgment matrix as shown in Eq. (1).

Table 2 Index layer scale comparison table

Range	Scaling	Range	Scaling
<0.1	2	1.5–2	6
0.1–0.5	3	2–2.5	7
0.5–1	4	2.5–3	8
1–1.5	5	3–3.5	9

Table 3 Standard-level scale comparison table

Range	Scaling	Range	Scaling
0.1–1	2	4–5	6
1–2	3	5–6	7
2–3	4	6–7	8
3–4	5	7–8	9

$$f_1 = \begin{bmatrix} 1 & 1/25 & 2 \\ 2 & 15 & 3 \\ 1/5 & 1/51 & 1/4 \\ 1/2 & 1/34 & 1 \end{bmatrix} \quad f_2 = \begin{bmatrix} 1 & 1/21 & 3 & 1/3 & 1/4 \\ 2 & 11/2 & 1/3 & 1/4 \\ 3 & 22 & 1/2 & 1/4 \\ 3 & 32 & 1 & 1/4 \\ 4 & 44 & 4 & 1 \end{bmatrix} \quad (1)$$

(2) We calculate the normalized index weight and obtain the most significant characteristic root $\lambda_{\max}$ and consistency test of the judgment matrix.

$$\omega_i = \frac{(\prod_{j=1}^m a_{ij})^{1/m}}{\sum (\prod_{j=1}^m a_{ij})^{1/m}} (i, j = 1, 2, \dots, m) \quad (2)$$

$$C_R = C_I / R_I \quad (3)$$

Among them, $C_I = (\lambda_{\max} - m) / (m - 1)$ is the consistency index of the deviation rate; R_I is the average random consistency index, which represents the average consistency index of the average deviation rate. We use MATLAB to repeat the random judgment matrix calculation results 10,000 times, as shown in Table 4.

Table 4 Average random consistency index value standard

<i>m</i>	RI
1–2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51

(3) Calculate the weights of multiple-level indicators. Considering the influence of the first-level indicators at the criterion level on the index factors, we calculate the comprehensive weight as the product of the two-level weights. The results are shown in Table 5.

Table 5 Analytic hierarchy process to determine the weight distribution of indicators

Index	A1	B11	B12	B13	B14	B15
Sibling weight	0.2929	0.0672	0.0936	0.1446	0.2099	0.4846
Comprehensive weight		0.0197	0.0274	0.0424	0.0615	0.1419
Index	A2	B21	B22	B23	B24	
Sibling weight	0.4647	0.2094	0.2966	0.4195	0.0742	
Comprehensive weight		0.0973	0.1378	0.1949	0.0345	
Index	A3	B31	B32	B33	B34	
Sibling weight	0.0634	0.1155	0.231	0.4901	0.1634	
Comprehensive weight		0.0073	0.0146	0.0311	0.0104	
Index	A4	B41	B42	B43		
Sibling weight	0.1791	0.0811	0.342	0.5769		
Comprehensive weight		0.0145	0.0613	0.1033		

Analysis of the results in Table 6 shows that the value of C_R in the table is <0.1 . Therefore, we can judge that its construction matrix is reasonable and adequate and that it meets the consistency requirements.

Table 6 Consistency judgment of analytic hierarchy process

Level	λ_{max}	CR	CI
A1–A4	4.098	0.0327	0.0363
B11–B15	5.2534	0.0566	0.0634
B21–B24	4.1213	0.0449	0.0404
B31–B32	4.1213	0.0449	0.0404
B41–B43	3.0291	0.0251	0.0145

3.2 Coefficient of variation method to determine objective weight

The coefficient of variation method uses the standard deviation and mean of each index data to directly calculate the index weight. The change in difference between indicator data is proportional to the weight. The

greater the difference, the greater is the weight, and the more critical is the impact on the evaluation result [8]. The specific calculation method is as follows:

(1) Calculate the coefficient of variation of the i -th group of indicators

$$C_i = \frac{\sigma_i}{\bar{m}_i} \quad (4)$$

where σ_i is the standard deviation of the i -th group of index data, and $\bar{m}_i$ is the arithmetic mean of the i -th group of index data.

(2) We use the weight calculation in Eq. (5) of the multiple-level indicators to obtain the weight distribution of the indicators.

$$\omega_i = \frac{V_i}{\sum V_i} \quad (5)$$

3.3 Game theory combination weighting method

The game theory analysis method finds the minimization difference between the optimal weight and the different weights of each index to obtain the optimal evaluation index weight. The specific steps are as follows:

(1) We set up a vector set of basic weights for the evaluation indicators of subject competition innovation ability: $w_k = \{w_{k1}, w_{k2}, \dots, w_{km}\}, k = 1, 2, \dots, L$, where w_k is the set of weights determined by the k -weighting method, and m is the number of evaluation indicators [9]. In this paper, $L = 2, m = 16$. Let $a = \{a_1, a_2\}$ be the linear combination coefficient, and the comprehensive weight vector w satisfies any linear combination of the two vectors as follows:

$$\omega = \sum_{k=1}^L a_k \cdot \omega_k^T (\alpha_k > 0). \quad (6)$$

(2) Optimize the weight vector a_k of the two weight vectors. We obtain the optimal weight w^* by minimizing the range between w and w_k . In other words, the optimization objective function is as follows:

$$\min_{a_k > 0} \left\| \sum_{k=1}^2 a_k \cdot \omega_k^T - \omega_k \right\|_2 \quad (7)$$

(3) Obtain the linear equation system form corresponding to the objective function according to the matrix differential property.

$$\begin{bmatrix} \omega_1 \omega_1^T & \omega_1 \omega_2^T \\ \omega_2 \omega_1^T & \omega_2 \omega_2^T \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \omega_1 \omega_1^T \\ \omega_2 \omega_2^T \end{bmatrix} \quad (8)$$

We solve the matrix Eq. (8) to obtain the combination coefficient $a_1 = 0.4377, a_2 = 0.8028$. The normalized processing obtains the weight vector $a_1^* = 0.3528, a_2^* = 0.6472$ and the final evaluation index combination total weight.

$$\omega^* = \sum_{k=1}^2 a_k^* \omega_k^T \quad (9)$$

We use MATLAB to calculate the combined total weights, as shown in Table 7.

It can be seen from Table 7 that the index elements B15, B22, and B23 have larger weights, followed by B21 and B43, and the remaining ones are even less critical. We compare the actual survey and statistical results of subject competitions between 2017 and 2020. The example shows that the main index factors that influence the innovation ability of college students in subject competition are the ability to solve problems, the ability of teamwork, and the ability of communication and coordination [10]. However, the aspects of innovation and efficiency produced through subject competitions are relatively weak, related to the relatively weak subjective conversion consciousness of students' achievements and the insufficient accumulation of knowledge and abilities to a certain extent.

Table 7 The method of coefficient of variation and game theory to determine the weight distribution of indicators

Index	Coefficient of variation	Game theory combination	Index	Coefficient of variation	Game theory combination
B11	0.0515	0.0309	B24	0.0496	0.0398
B12	0.0510	0.0357	B31	0.0932	0.0376
B13	0.0503	0.0452	B32	0.0914	0.0417
B14	0.0500	0.0574	B33	0.0879	0.0511
B15	0.0454	0.1079	B34	0.0919	0.0392
B21	0.0458	0.0791	B41	0.1140	0.0496
B22	0.0456	0.1053	B42	0.0461	0.0559
B23	0.0453	0.1421	B43	0.0411	0.0814

Figure 1 is a graph of the weighting result of the evaluation method. The analysis available is affected by the correlation between subjective factors and indicator elements. The AHP highlights the weight of the ability factor and weakens the weight of the benefit factor [11]. The coefficient of variation method analyzes the original sample data of the indicator elements, and the two criterion levels of scientific and technological innovation achievements and scientific and technological education benefits fluctuate considerably. This highlights the weight of the benefit factor result. The weighted result obtained by the combination weight method of game theory based on the theory of minimization of difference equilibrium is located between the two. The weight of the 16 index factors has been balanced to a certain extent. Therefore, we have obtained relatively good weighting results.

Fig. 1 Results of weight comparison.

4 Conclusion

We start by constructing subjective evaluation indicators and objective evaluation indicators based on the game theory to balance personal empowerment and objectiveness. Then, the weight set is assigned to determine the complete optimal weight result. Finally, in response to the above theoretical results, suggestions for improving college students' creative ability are proposed: creating a relaxed learning environment for practicing innovative personality development, encouraging students to understand cutting-edge technologies in science and technology, condensing scientific research issues, and proposing innovative ideas and opinions; building a

multilevel open development platform; providing a suitable environment for students to obtain hands-on practice; strengthening the ability of teachers of innovation and entrepreneurship; and guiding the cultivation and development of students' creative ability. In addition, attention should be paid to cultivating students' innovative ideological awareness and practical ability, strengthening the accumulation of knowledge and ability, and enhancing the transformation of results to implement each training link.

References

- [1] Hahn, D., Minola, T., Bosio, G., & Cassia, L. The impact of entrepreneurship education on university students' entrepreneurial skills: a family embeddedness perspective. *Small Business Economics*, 2020. 55(1): 257-282.
- [2] Nakku, V. B., Agbola, F. W., Miles, M. P., & Mahmood, A. The interrelationship between SME government support programs, entrepreneurial orientation, and performance: A developing economy perspective. *Journal of Small Business Management*, 2020. 58(1): 2-31.
- [3] PRAMONO, R., Sondakh, L. W., BERNARTO, I., JULIANA, J., & PURWANTO, A. Determinants of the Small and Medium Enterprises Progress: A Case Study of SME Entrepreneurs in Manado, Indonesia. *The Journal of Asian Finance, Economics, and Business*, 2021. 8(1): 881-889.
- [4] Luu, N., & Ngo, L. V. Entrepreneurial orientation and social ties in transitional economies. *Long Range Planning*, 2019. 52(1): 103-116.
- [5] Hwang, W. S., Choi, H., & Shin, J. A mediating role of innovation capability between entrepreneurial competencies and competitive advantage. *Technology Analysis & Strategic Management*, 2020. 32(1): 1-14.
- [6] Boudreaux, C. J., Nikolaev, B. N., & Klein, P. Socio-cognitive traits and entrepreneurship: The moderating role of economic institutions. *Journal of Business Venturing*, 2019. 34(1): 178-196.
- [7] Li, H., Terjesen, S., & Umans, T. Corporate governance in entrepreneurial firms: A systematic review and research agenda. *Small Business Economics*, 2020. 54(1): 43-74.
- [8] Eesley, C. E., & Lee, Y. S. Do university entrepreneurship programs promote entrepreneurship?. *Strategic Management Journal*, 2021. 42(4): 833-861.
- [9] Singh, A. K., & Ashraf, S. N. Association of entrepreneurship ecosystem with economic growth in selected countries: An empirical exploration. *Journal of Entrepreneurship, Business and Economics*, 2020. 8(2): 36-92.
- [10] Prüfer, J., & Prüfer, P. Data science for entrepreneurship research: studying demand dynamics for entrepreneurial skills in the Netherlands. *Small Business Economics*, 2020. 55(3): 651-672.
- [11] Arvidsson, H. G., Coudounaris, D. N., & Arvidsson, R. The shift from causation to effectuation for international entrepreneurs: Attitudes and attitude change versus social representations. *International Journal of Entrepreneurship*, 2020. 24(3): 1-23.