Evaluation of Teachers’ Innovation and Entrepreneurship Ability in Universities Based on Artificial Neural Networks

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ABSTRACT

Based on iceberg theory and the questionnaire of competency’s elements, hierarchical index system of evaluation of teachers’ innovation and entrepreneurship competency in universities is established. Through researches, the authors think that analytic hierarchy process (AHP) is a more scientific and reasonable evaluation method whose rationality is checked by satisfactory consistency while the evaluation model of artificial neutral network doesn’t consider weighting. If the samples are more than 30, the evaluation of neural network model of teachers’ innovation and entrepreneurship competency can achieve the accurate results and satisfactory requirements. Since the method of artificial neutral network has advantages of strong operability, simple rules, and minor errors, it can greatly reduce the workload because it not only eliminates human subjectivity of evaluation and greatly simplifies the process of evaluation, but also improves working efficiency and provides a new way of thinking for evaluation of the teachers’ innovation and entrepreneurship competency in universities.

KEYWORDS
AHP, Artificial Neural Network, Competency Evaluation, Innovation and Entrepreneurship Competency

1. INTRODUCTION

As China’s economy has ushered in a new normal and the economic growth is innovation-driven other than previously investment- and factor-driven, innovation and entrepreneurship research has become a focused area in higher vocational colleges. As the direct performers of talent training, teachers need to strengthen their innovation and entrepreneurship competency so as to improve the overall level of these competencies in higher vocational colleges. However, in the academic circle, there is a research gap in the evaluation and promotion strategies of college teachers’ innovation and entrepreneurship competency. How to evaluate the innovation and entrepreneurship competency of teachers in the higher vocational colleges to help improve such competencies has become one of the core issues in the reform and development of higher vocational education(Lee et al.,2011; White,1959).
Iceberg model theory was put forward by famous American psychologist McClelland in 1973 (McClelland, 1973). According to the different manifestation of individual qualities, professor McClelland classified iceberg into two parts, one is superficial “part of the iceberg above the surface,” and the other is deep “part of the iceberg below the surface” The “part of the iceberg above the surface” that includes knowledge and skills are the external manifestations which can easily be understood and measured. Thus they are relatively easy to change through training and development. The “part of the iceberg below the surface” that includes social roles, self-image, features, and motivation are the internal manifestation and difficult to be measured. Although this part is less likely to be influenced and changed by the surroundings, it plays a crucial role in people’s behavior and performance. McClelland thinks that traditional intelligence and aptitude tests cannot predict people’s professional success and other important achievements (McClelland, 1998). He advocates the exploration of individual conditions and real behavioral characteristics, which is called the competency that affects job performance. Many researchers believe that the competency model is becoming an important part of human resource management, so modern enterprise management should use competency evaluation to predict job performance (Shipmann et al., 2000; Sandberg, 2002; Yamazaki, 2014; Parry, 2009; Smolensky, 1986).

Western studies of competency evaluation of teachers in universities started earlier. Representative methodologies are as follows: balanced scorecard, statistical analysis, Markov chain method, Analytic Hierarchy Process (AHP), comprehensive evaluation method, management by objectives, key performance indicators (Spencer and Spencer, 1993; Boyatzis, 1982; Glockshuber, 2007; Stewart, 2010; Erlich and Shaughnessy, 2014) and so on. Chinese scholars have been continually improving and complementing models, methods, and techniques of teachers’ competency evaluation on the foundation of the experiences and results of western studies (Zhong, 2011). Scholars such as Wang (2005), Qin (2007), and Zhang (2009) have used the method of 360-degree feedback on the evaluation of teachers’ performance, putting forward relevant evaluation criteria, procedures, and implementing strategies. Guo (2006), Xu (2007), and Cao (2012) have studied programs, models, and management of the performance evaluation of the teachers based on the balanced scorecard in universities. Xu (2007) has used AHP and fuzzy mathematics to establish an evaluation model. Zhu (2007) has analyzed the cases in universities by means of rough set theory and distinguished matrix to explore the rules of evaluation and obtain objective weighting of evaluating factor. Chen (2012) has made empirical analysis on the evaluation of teachers, suggesting the index of evaluation should be designed from developing strategies in the university. Su (2007) has applied AHP to the evaluation of teachers to determine the weight and build the right index of the evaluation system. Huang et al. (2020) have analyzed the influence of university students’ learning beliefs on their intentions to use mobile technologies in learning. Owusu (2020) has analyzed the determinants of Cloud Business Intelligence Adoption Among Ghanaian SMEs. Amo et al. (2020) has designed and implemented a solution based on a student’s data pseudonymization through aliases to enable adequate levels in confidentiality issues.

In summary, there are some achievements in the research methods of the current evaluation of teachers in universities at home and abroad. However, researches on the evaluation performance of the teachers’ innovation and entrepreneurship competency by means of neural network in universities are rarely few. Many universities in PETOE haven’t established a scientific system of evaluation in accordance with the characteristics and job requirements of teachers’ innovation and entrepreneurship competency in universities. Evaluation of teachers’ innovation and entrepreneurship competency has become an important breakthrough in human resources management in universities.

As for the neural network, it is a very important area for people to explore mimicking the human brain system to process information (Poggio and Giroisi, 1990; Saavedra-Rivano, 2020). From the M-P neuron model established by psychologist McCulloch and Pitts in 1943 up to now, the neural network model, learning algorithms, implementation, and application of neural computer have made encouraging fruitful results. The most important difference of the neural network evaluation method is in the form of intelligent computing that can avoid subjectivity. As a branch of artificial intelligence,
the neural network is similar to the basic structure of computer program of human brain learning (Stinchcombe and White, 1989). Compared with other methods, another important advantage of the neural network is more powerful in data processing, which contributes to its special structure. There are a limited number of the neutral hidden layer which can estimate any continuous function and ultimately achieve the desired accuracy (Narendra and Parthasarathy, 1990). A neuron represents the receiving, processing, transmitting data model to the next level of processing unit time.

Under ideal conditions, in the face of a particular task, the neural network must be optimized in the composition of the entire parameter space of learning rate, momentum rate, implied layer, the number of nods, the combination of input variables, triggering functions, and so on. To achieve optimization, the computational burden may be relatively large. In this regard, neural network design is considered an art rather than a science (Kawakami and Hirasawa, 1992). Anyway, the main goal of the design of a neural network is to minimize error. In other words, it can also be considered to optimize the network topology (Widrow and Lehr, 1990). With the further improvement and development of the neural network, it will play a greater crucial role in science and technology.

In view of the fact that the artificial neural network can fully approximate any complex nonlinear relationship and has strong robustness and fault tolerance, it can learn and adapt to unknown or uncertain systems and can process quantitative and qualitative knowledge at the same time, and this paper attempts to apply neural network into the evaluation of teachers’ innovation and entrepreneurship competency with the theory of iceberg model and the foundation and comparison of AHP method to achievement a relatively more accurate and intelligent way to evaluate teachers’ innovation and entrepreneurship competency in universities.

2. CASE OF EVALUATION OF AHP OF TEACHERS’ INNOVATION AND ENTREPRENEURSHIP COMPETENCY IN W UNIVERSITY

2.1 Establishment of Evaluation System of Teachers’ Innovation and Entrepreneurship Competency

At present, there are a number of factors of the evaluation of teachers’ innovation and entrepreneurship competency in universities, and the structure is complicated. According to the characteristics of the work of teachers’ innovation and entrepreneurship competency in universities and the competency model of iceberg theory proposed by Spencer, this paper establishes hierarchical structure (see Table 1) from four aspects of Feature Competency, Technology Competency, Practice Competency, and Society Competency as well. The uppermost layer is called the target layer, which is a predetermined objective to analyze the problem. The intermediate layer is called the criterion layer or index layer, and the lowermost layer is called the scheme layer or object layer. The structure of evaluation of teachers’ innovation and entrepreneurship competency is as follows: The structure of feature competency refers to teachers’ quality in innovation, which is for teachers to complete innovation and entrepreneurship education work. The structure of technology competency reflects teachers’ relevant skills in innovation. Practice competency reflects college teachers’ entrepreneurial practice-related competency, and society competency reflects college teachers’ ability to adapt to society. Among the four dimensions of competency, feature competency and society competency can be regarded as invisible competencies, while technology competency and practice competency are visible competencies.

This paper uses SPSS19.0 for the sample questionnaires, and we find two coefficients are both more than 90%, so there are high internal consistency and strong reliability for the questionnaires, which can be analyzed in depth (see table 2).

Reliability analysis of the questionnaire of the importance of elements of teachers’ innovation and entrepreneurship competency in universities is shown in Table 1.
2.2 Establishment of Judgment Matrix

The judgment matrix is fundamental to calculate importance. We assume that the target layer of “U" has the dominant relationship to the object layer U₁, U₂, U₃, U₄. For the target layer U, the importance of Uᵢ and Uⱼ need to be compared and determined, and the “importances" need to be given certain values. For the 4 index elements of the indicators, pairwise comparison judgment matrix(Uᵢⱼ)₄×₄ can be obtained. Uᵢⱼ represents how important the indicators of Uᵢ and Uⱼ for targets.

Index System of Innovation and Entrepreneurship Competency Evaluation is shown in Table 2. Obviously, matrix(Uᵢⱼ)₄×₄ is featured as follows:

1) Uᵢⱼ > 0
2) Uᵢⱼ = 1/(Uⱼᵢ)
3) Uᵢᵢ = 1/(i,j=1,2,3,4)

For matrix(Uᵢⱼ)₄×₄, if for any i, j, k, there is Uᵢⱼ • Uⱼₖ = Uᵢₖ, the matrix(Uᵢⱼ)₄×₄ is the consistent matrix.

To determine the specific values of the judgment matrix, T.L.Saaty proposed the scale of 1-9, and the meaning is shown in table 3:

In this paper, the layer U of performance objective of teachers' innovation and entrepreneurship competency in universities for the next layer index layer U₁, U₂, U₃, U₄ and the judgment of the matrix of the index layer and the object layer are formed by seven experts who fill in the inquiry forms (see tables from 4 to 8).

Judgment matrix of U — index layer Uᵢ of indicator system of innovation and entrepreneurship competency is shown in table 4.

Judgment matrix of U₁— object layer of indicator system of innovation and entrepreneurship competency is shown in Table 5.

Judgment matrix of U₂— object layer of indicator system of innovation and entrepreneurship competency is shown in Table 6.

Judgment matrix of U₃— object layer of indicator system of innovation and entrepreneurship competency is shown in Table 7.

Judgment matrix of U₄— object layer of indicator system of innovation and entrepreneurship competency is shown in Table 8.

2.3 Consistency Check

Only when the matrix is exactly consistent, there is λ₁=λₘₐₓ=n, and other latent roots are zero; when judgment matrix is not exactly consistent, λₘₐₓ=n, other latent roots have the following relationship (see equation 1):

\[ \sum_{i=2}^{n} \lambda_i = n - \lambda_{\text{max}} \]  \hspace{1cm} (1)
| Target Tier | Criterion Tier | Level 1 Indicator | Code | Level 2 Indicator | Code |
|-------------|----------------|-------------------|------|-------------------|------|
| Innovation and Entrepreneurship Competency Evaluation of Teachers in Industry-Oriented Higher Vocational Colleges | Innovation Competency | Feature Competency | U1   | Innovation Willpower | U11  |
|             |                |                   |      | Innovation Thinking | U12  |
|             |                |                   |      | Achievement Motivation | U13  |
|             |                |                   |      | Risk-taking Propensity | U14  |
|             |                |                   |      | Emotional Stability | U15  |
|             |                |                   |      | Decisive Power for Action | U16  |
|             |                |                   |      | Independent Work Competency | U17  |
|             | Technical Competency | U2 | Technical Learning Competency | U21  |
|             |                |                   |      | Technology Development Competency | U22  |
|             |                |                   |      | Knowledge Transformation Competency | U23  |
| Entrepreneurship Competency | Practice Competency | U3 | Opportunity Recognition Competency | U31  |
|             |                |                   |      | Enterprise Management Competency | U32  |
|             |                |                   |      | Risk Prevention Competency | U33  |
|             |                |                   |      | Financial Management Competency | U34  |
|             |                |                   |      | Market Development Competency | U35  |
|             |                |                   |      | Marketing Competency | U36  |
|             |                |                   |      | Human Resources Management Competency | U37  |
| Society Competency | U4 | Leadership | U41  |
|             |                | Communication Competency | U42  |
|             |                | Self-control Competency | U43  |
|             |                | Environmental Resilience Competency | U44  |
|             |                | Teamwork Competency | U45  |
|             |                | Resource Integration Competency | U46  |
|             |                | Problem Solving Competency | U47  |
Table 3. Scale of judgment matrix and its meaning

| No. | Element importance level(i to j)                                      | Uij valuation |
|-----|-----------------------------------------------------------------------|---------------|
| 1   | i is equally important with j                                         | 1             |
| 2   | i is a little bit important than j                                    | 3             |
| 3   | i is obviously important than j                                       | 5             |
| 4   | i is strongly important than j                                        | 7             |
| 5   | i is extremely important than j                                       | 9             |
| 6   | i is a little bit less important than j                               | 1/3           |
| 7   | i is obviously less important than j                                  | 1/5           |
| 8   | i is strongly less important than j                                   | 1/7           |
| 9   | i is extremely less important than j                                  | 1/9           |

NOTE: \( U_{ij} = \{2,4,6,8,1/2,1/4,1/6,1/8\} \) indicates their levels of importance between \( U_{ij} = \{1,3,5,7,9,1/3,1/5,1/7,1/9\} \).

Table 4. Judgment matrix of \( U_i \)

| U  | \( U_1 \) | \( U_2 \) | \( U_3 \) | \( U_4 \) |
|----|------------|------------|------------|------------|
| \( U_1 \) | 1          | 1/2        | 2          | 3          |
| \( U_2 \) | 2          | 1          | 3          | 4          |
| \( U_3 \) | 1/2        | 1/3        | 1          | 2          |
| \( U_4 \) | 1/3        | 1/2        | 1/4        | 1          |

Table 5. Judgment matrix of \( U_{ii} \)

| U_1 | U_{11} | U_{12} | U_{13} | U_{14} | U_{15} | U_{16} | U_{17} |
|-----|--------|--------|--------|--------|--------|--------|--------|
| \( U_{11} \) | 1      | 1      | 1/3    | 1/2    | 1      | 1      | 1/4    |
| \( U_{12} \) | 1      | 1      | 1/3    | 1/2    | 1      | 1      | 1/5    |
| \( U_{13} \) | 3      | 3      | 1      | 2      | 3      | 3      | 1/2    |
| \( U_{14} \) | 2      | 2      | 1/2    | 1      | 2      | 2      | 1/3    |
| \( U_{15} \) | 1      | 1      | 1/3    | 1/2    | 1      | 1      | 1/5    |
| \( U_{16} \) | 1      | 1      | 1/3    | 1/2    | 1      | 1      | 1/6    |
| \( U_{17} \) | 4      | 5      | 2      | 3      | 5      | 6      | 1      |

Table 6. Judgment matrix of \( U_{ij} \)

| U_2 | U_{21} | U_{22} | U_{23} |
|-----|--------|--------|--------|
| \( U_{21} \) | 1      | 1/2    | 3      |
| \( U_{22} \) | 2      | 1      | 5      |
| \( U_{23} \) | 1/5    | 1/3    | 1      |
Therefore, the difference $\lambda_{\text{max}} = n$ can be used to test the degree of coherence. At present, CI (Consistency Index) is used as the consistency index (see equation 6). The smaller the CI is, the greater the consistency is.

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]  

(2)

Obviously, for the mutual consistent positive and negative matrix, there is CI=0, $\lambda_1 = \lambda_{\text{max}} = n$. Judgment matrix is completely consistent. But, it is not enough to rely on value CI to judge whether there is a consistency check for matrix A. Sometimes the average random consistency index RI needs to be introduced. Value R from band 1 to 9 is shown in Table 9.

Index of average consistency is shown in Table 9.

For 1 and 2 order judgment matrix, RI is only formal. When CR=CI/RI<0.1, there is satisfactory consistency for the judgment matrix. After calculation, the judgment matrix has passed the consistency test. Results are shown in Table 10.

Table 7. Judgment matrix of $U_3$

| $U_3$ | $U_{31}$ | $U_{32}$ | $U_{33}$ | $U_{34}$ | $U_{35}$ | $U_{36}$ | $U_{37}$ |
|-------|---------|---------|---------|---------|---------|---------|---------|
| $U_{31}$ | 1  | 1/4 | 1/3 | 1 | 1/3 | 1/3 | 1/6 |
| $U_{32}$ | 4 | 1 | 2 | 4 | 2 | 3 | 1/2 |
| $U_{33}$ | 3 | 1/2 | 1 | 3 | 1 | 2 | 1/4 |
| $U_{34}$ | 1 | 1/4 | 1/2 | 1 | 2 | 1/2 | 1/7 |
| $U_{35}$ | 3 | 1/2 | 1 | 1/2 | 1 | 2 | 1/3 |
| $U_{36}$ | 3 | 1/3 | 1/2 | 2 | 1/2 | 1 | 1/5 |
| $U_{37}$ | 6 | 2 | 4 | 7 | 3 | 5 | 1 |

Table 8. Judgment matrix of $U_4$

| $U_4$ | $U_{41}$ | $U_{42}$ | $U_{43}$ | $U_{44}$ | $U_{45}$ | $U_{46}$ | $U_{47}$ |
|-------|---------|---------|---------|---------|---------|---------|---------|
| $U_{41}$ | 1 | 2 | 2 | 1 | 3 | 3 | 2 |
| $U_{42}$ | 1/2 | 1 | 1 | 1/2 | 2 | 2 | 1 |
| $U_{43}$ | 1/2 | 1 | 1 | 1/2 | 2 | 2 | 1 |
| $U_{44}$ | 1 | 2 | 2 | 1 | 3 | 3 | 2 |
| $U_{45}$ | 1/3 | 1/2 | 1/2 | 1/3 | 1 | 1 | 1/2 |
| $U_{46}$ | 1/3 | 1/2 | 1/3 | 1/3 | 1 | 1 | 1/2 |
| $U_{47}$ | 1/2 | 1 | 1/3 | 1/2 | 2 | 2 | 1 |

Table 9. Index of average consistency

| $n$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----|---|---|---|---|---|---|---|---|---|
| RI  | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |
2.4 Hierarchical Ordering

Judgment matrix is the calculated basis of AHP. \( AW=\lambda_{\text{max}}W \) is used to solve \( \lambda_{\text{max}} \) corresponding feature vector \( W \) of \( \lambda_{\text{max}} \), which is normalized, namely the weighting coefficient of the corresponding index of the same level for some indicator of the top level. The root method is used in this paper. Calculating methods are seen in formula (3), formula (4), and (5). The results are in table 11.

### Table 10. Calculating results of consistent

| Target-U | CR    | \( \lambda_{\text{max}} \) | CI    | RI   |
|----------|-------|-----------------|-------|------|
| Feature Competency - \( U_1 \) | 0.0031 | 7.0247 | 0.0041 | 1.32 |
| Technology Competency - \( U_2 \) | 0.0032 | 3.0037 | 0.0018 | 0.58 |
| Practice Competency - \( U_3 \) | 0.0559 | 7.4431 | 0.0739 | 1.32 |
| Society Competency - \( U_4 \) | 0.0026 | 7.0203 | 0.0034 | 1.32 |

### Table 11. Total weight of each element

| 1st level | weight | 2nd level | Stratification weight |
|-----------|--------|-----------|-----------------------|
| \( U_1 \) | 0.2776 | \( U_{11} \) | 0.0729 |
|           |        | \( U_{12} \) | 0.0706 |
|           |        | \( U_{13} \) | 0.2151 |
|           |        | \( U_{14} \) | 0.1320 |
|           |        | \( U_{15} \) | 0.0706 |
|           |        | \( U_{16} \) | 0.0688 |
|           |        | \( U_{17} \) | 0.3699 |
| \( U_2 \) | 0.4668 | \( U_{21} \) | 0.3090 |
|           |        | \( U_{22} \) | 0.5816 |
|           |        | \( U_{23} \) | 0.1095 |
| \( U_3 \) | 0.1603 | \( U_{31} \) | 0.0442 |
|           |        | \( U_{32} \) | 0.2139 |
|           |        | \( U_{33} \) | 0.1251 |
|           |        | \( U_{35} \) | 0.0592 |
|           |        | \( U_{36} \) | 0.1009 |
|           |        | \( U_{37} \) | 0.0802 |
|           |        | \( U_{37} \) | 0.3766 |
| \( U_4 \) | 0.0953 | \( U_{41} \) | 0.2371 |
|           |        | \( U_{42} \) | 0.1287 |
| \( U \)   |        | \( U_{45} \) | 0.1287 |
|           |        | \( U_{46} \) | 0.2371 |
|           |        | \( U_{46} \) | 0.0699 |
|           |        | \( U_{47} \) | 0.0699 |
|           |        | \( U_{47} \) | 0.1287 |
1) To calculate the product $M_i$

$$M_i = \prod_{j=1}^{n} a_{ij} \quad (i = 1, 2, \ldots, n)$$

(3)

To calculate the $n$-th root $\bar{o}_{ii}$

$$\bar{W}_i = \sqrt[n]{M_i}$$

(4)

To normalize the vector $1, 2, \ldots, n^T$

$$W_i = \frac{\bar{W}_i}{\sum_{j=1}^{n} \bar{W}_j}$$

(5)

Therefore, $W=W_1, W_2, \ldots, W_n^T$ is the feature vector of seeking weight.

Therefore weight vector of a set of elements for some element on a topper layer is obtained, and finally, the sequence weight of the various elements of the level of the lowest program for the target is gained. Thereby, the selection of program is conducted. The calculation of the total weight is composed of the top down in accordance with a single criterion.

In order to facilitate research, only part of the data of the questionnaire of competency evaluation is selected in W University. We select 34 questionnaires of self-evaluation of teachers’ innovation and entrepreneurship competency as samples and calculate the results according to the weight determined in table11. Results are shown in Table 12.

3. APPLICATION OF EVALUATION OF ARTIFICIAL NEURAL NETWORKS OF TEACHERS’ INNOVATION AND ENTREPRENEURSHIP COMPETENCY IN GRP

The factors of evaluation of teachers’ innovation and entrepreneurship competency in universities are Innovation Willpower, Innovation Thinking, Achievement Motivation, Risk-taking Propensity, Emotional Stability, Decisive Power for Action, Independent Work Competency, Technical Learning Competency, Technology Development Competency, Knowledge Transformation Competency, Opportunity Recognition Competency, Enterprise Management Competency, Risk Prevention Competency, Financial Management Competency, Market Development Competency, Marketing Competency, Human Resources Management Competency, Leadership, Communication Competency, Self-control Competency, Environmental Resilience Competency, Teamwork Competency, Resource Integration Competency, and Problem Solving Competency. Results and inclusions of 34 self-assessment are taken for the study samples, using Matlab R2012b to make simulation evaluation.

Using $x_{ij}$ to represent the evaluation score of $i$-th element of the $j$-th teacher in the original data, $i = 1, 2, \ldots, 24$, $j = 1, 2, \ldots, 34$. $y_j$ shows evaluation score of the $j$-th teacher in raw data, $j = 1, 2, \ldots, 34$. 30 teachers from ZP001 to ZP030 are chosen as the learning sample set, 4 data from teacher ZP031 to ZP034 as the test sample set. Network is trained by the means of learning sample set and then the trained neural network is used to evaluate teachers from ZP031-034 to obtain evaluating value of the networks, which are compared with the actual value of the test samples.
### Table 12. Results of evaluation of AHP of teachers’ innovation and entrepreneurship competency in W university

| No.  | Sex | Age | Title  | Score of evaluation |
|------|-----|-----|--------|---------------------|
| ZP001| M   | 38  | lecturer | 8.171236          |
| ZP002| M   | 53  | A.P.    | 8.057526           |
| ZP003| M   | 46  | A.P.    | 8.051344           |
| ZP004| M   | 36  | lecturer | 8.384824          |
| ZP005| M   | 39  | A.P.    | 7.957929           |
| ZP006| M   | 36  | lecturer | 8.261267          |
| ZP007| M   | 35  | lecturer | 8.625388           |
| ZP008| M   | 36  | A.P.    | 7.031283           |
| ZP009| M   | 38  | A.P.    | 7.072217           |
| ZP010| M   | 45  | Prof.   | 8.247954           |
| ZP011| M   | 32  | lecturer | 7.214198          |
| ZP012| M   | 43  | Prof.   | 7.595864           |
| ZP013| M   | 48  | Prof.   | 8.536483           |
| ZP014| M   | 44  | A.P.    | 7.567526           |
| ZP015| M   | 31  | lecturer | 8.492185          |
| ZP016| M   | 53  | A.P.    | 8.385913           |
| ZP017| M   | 55  | Prof.   | 7.743958           |
| ZP018| M   | 38  | A.P.    | 8.560462           |
| ZP019| M   | 44  | Prof.   | 7.810079           |
| ZP020| M   | 48  | A.P.    | 8.185521           |
| ZP021| M   | 36  | lecturer | 8.419903          |
| ZP022| F   | 35  | lecturer | 8.610484          |
| ZP023| F   | 48  | Prof.   | 7.95943            |
| ZP024| F   | 33  | assistant | 8.210952         |
| ZP025| F   | 32  | lecturer | 7.241441          |
| ZP026| F   | 44  | A.P.    | 8.124543           |
| ZP027| F   | 36  | assistant | 8.378991          |
| ZP028| F   | 32  | assistant | 8.476565          |
| ZP029| F   | 58  | Prof.   | 7.827661           |
| ZP030| F   | 33  | lecturer | 7.982569           |
| ZP031| F   | 34  | assistant | 7.996101         |
| ZP032| F   | 40  | A.P.    | 8.16841            |
| ZP033| F   | 37  | lecturer | 7.610157           |
| ZP034| F   | 34  | assistant | 8.007975          |

### 3.1 Normalization of Sample Data

In order to eliminate the differential of the raw data, generally the data requires a unified dimension. So here the function premnmx of Matlab is selected to pre-process and post-process the raw data. Normalization algorithm of the function is shown as the formula (6) as follows:
\[ pn = 2 \ast (p - \text{min} p) / (\text{max} p - \text{min} p) - 1 \]  

(6)

in which: \( pn \) is the standardized input matrix of \( R \times Q \) dimension; \( p \) is the input matrix of dimension \( R \times Q \); \( \text{min} p \) is the vector of minimum value of each component of \( p \) which is included in \( R \times 1 \) dimension; \( \text{max} p \) is the vector of the maximum value of each component of \( p \) which is included in \( R \times 1 \) dimension.

3.2 Determination of the Number of the Nodes in Hidden Layer

BP (Back Propagation) neural network is widely used as about 80% of the neural network models have used BP networks or the variant forms (Szewezyk and Hajela, 1994). So BP neural networks are chosen to evaluate teachers' innovation and entrepreneurship competency in W university. However, in practice, estimation of nodes in hidden layer has been a difficult key in network structure. The current researches are numerous, but there are still no definite conclusions. In 1989, Robert Hecht-Nielsen demonstrated a BP network with 3-layer, which can be mapped from \( n \)-dimension to \( m \)-dimension. That is to say, it can approach any continuous function. So there is 1 input layer, 24 nodes; a hidden layer, 1 node; 1 output layer, 1 node in the BP network designed here. The number of the l of nodes of the hidden layer is generally determined by:

\[ l = \sqrt{m + n + a} \]  

(7)

\[ l = \log_2 n \]  

(8)

\[ l = \sqrt{0.43mn + 0.12n^2 + 2.54m + 0.77n + 0.35 + 0.51} \]  

(9)

In (7) (8) (9), \( m \) is the number of the input nodes; \( n \) is the number of the output nodes; \( a \) is the constant between 1 to 10.

According to these empirical formulas, the number of the hidden layer nodes should be between 3 to 15. To confirm the number, 3 kinds of activation functions of tanh, elliotsig and logsig in MATLAB from node 1 to 18 for the simulation results are selected and compared. Results are shown in Table 13, Table 14 and Table 15 below.

From the results of table13, table 14, and table 15, the relative error of logsig function is minimized. In addition, the performance of different training functions will have an impact on the network. four kinds of training functions of the traingda, traingdm, traingdx and trainlm and network training are compared in this paper (see Figure 1 to Figure 4 (Neuron number of hidden layer is 6)).

Figure 1. Training results of traingdx function
Figure 2. Training results of traingda function

Figure 3. Training results of traingdm function

Figure 4. Training results of trainglm function
From figure 4, the requirement for network training error has reached in the case of smaller training steps with trainlm training function. The number of neurons in the hidden layer is chosen to be 6.

Therefore, the model of the BP neural network of evaluation of teachers’ innovation and entrepreneurship competency has confirmed an input layer, 24 nodes, logsig function of activation function; a hidden layer, six nodes, logsig function of activation function; an output layer, a node,

Table 13. Relative error of tansig function for each node selected

| No. of nodes | Tansig function | Relative error | Mean square error of relative error |
|--------------|-----------------|----------------|-------------------------------------|
|              | ZP031 | ZP032 | ZP033 | ZP034 | ZP031 | ZP032 | ZP033 | ZP034 |
| 1            | 7.6326 | 8.4207 | 7.6839 | 8.1435 | -5.460 | 3.088606 | 0.969008 | 1.692375 | 2.915841 |
| 2            | 8.3256 | 8.3681 | 7.3217 | 7.7047 | 4.1207 | 3.444662 | -3.79042 | -3.78716 | 3.593981 |
| 3            | 7.6261 | 8.3396 | 7.7808 | 8.2803 | -6.6273 | 2.095757 | 2.242306 | 3.400672 | 3.255623 |
| 4            | 7.9857 | 8.2296 | 7.9113 | 8.0532 | -0.1301 | 0.749105 | 3.957119 | 0.56475 | 2.034442 |
| 5            | 8.1057 | 8.28 | 7.7582 | 8.318 | 1.3707 | 1.366117 | 1.945334 | 3.871453 | 2.372628 |
| 6            | 8.0156 | 7.8639 | 7.5229 | 7.7017 | 0.243856 | -3.7279 | -1.14659 | -3.82462 | 2.734004 |
| 7            | 7.9333 | 8.2692 | 7.9315 | 7.7864 | -0.7854 | 1.2339 | 4.222554 | -2.76693 | 2.627985 |
| 8            | 8.109 | 7.8464 | 7.6549 | 7.918 | 1.411926 | -3.94214 | 0.587938 | -1.12357 | 2.187582 |
| 9            | 8.0347 | 8.3216 | 7.7514 | 8.1237 | 0.482723 | 1.875396 | 1.85598 | 1.445122 | 1.523415 |
| 10           | 8.3322 | 8.3546 | 7.9027 | 8.0773 | 4.203286 | 2.279391 | 3.844113 | 0.8657 | 3.097978 |
| 11           | 8.1569 | 8.0733 | 7.5095 | 7.7705 | 2.010968 | -1.16436 | -1.32267 | -2.96548 | 1.996451 |
| 12           | 7.9487 | 8.5079 | 8.1339 | 7.7683 | -0.5928 | 4.156133 | 6.882158 | -2.99295 | 4.299614 |
| 13           | 7.9665 | 7.986 | 7.8194 | 8.1451 | -0.37019 | -2.23312 | 2.749523 | 1.712355 | 1.975847 |
| 14           | 8.6759 | 8.4127 | 7.588 | 7.4754 | 8.501631 | 2.990668 | -0.29115 | -6.65056 | 5.602154 |
| 15           | 8.4101 | 8.2575 | 7.4894 | 8.7369 | 5.177511 | 1.090665 | -1.58679 | 9.102488 | 5.323752 |
| 16           | 8.4636 | 7.7097 | 8.0777 | 7.892 | 5.846587 | -5.61566 | 6.143671 | -1.44824 | 5.137127 |
| 17           | 8.2001 | 8.1615 | 7.8646 | 8.0588 | 2.551231 | -0.08459 | 3.343466 | 0.63468 | 2.127059 |
| 18           | 8.103 | 8.9869 | 7.9614 | 7.8806 | 1.336889 | 10.02019 | 4.61545 | -1.5906 | 5.613017 |
| Mean value   | 8.1125 | 8.2438 | 7.7591 | 7.9908 | 1.4559 | 0.9235 | 1.9567 | -0.21 | 3.2455 |
purelin function of the activation function (see figure 5). Training function of trainlm is selected, and MATLAB program code is omitted here. Evaluation results are obtained with the use of this network (see table 16). From the above results of the evaluation, the model of BP neural networks for evaluation of teachers’ innovation and entrepreneurship competency can achieve the effect of the AHP method (see table 12 and table 16). Compared with the testing results of AHP, the biggest error of the results by means of a neutral network is only 2.38%. Moreover, from the above results, it can be seen that the evaluation of teachers’ innovation and entrepreneurship competency based on AHP method has strong subjectivity, complicated operation hierarchies, and other problems. However, the evaluation based on ANN method with sample training, which is more intelligent, objective, and operational, can be directly used for the subsequent evaluation of teachers’ innovation and entrepreneurship competency.

4. CONCLUSION

The application of artificial neural networks into the evaluation of teachers’ innovation and entrepreneurship competency is an attempt to learn from nature. From the results of the evaluation, teachers can correct understanding of their own position, identify problems and improve themselves.

In practice, evaluation of teachers’ innovation and entrepreneurship competency is mainly operated in various colleges and universities, and the use of AHP evaluation will involve different weights, so in general, the results of the evaluation in various universities will be different because of the different emphasis. Even in the same universities, they have different focuses and evaluation results in the past, at present, and in the future. The advantages of the evaluation of neural networks will not

Table 14. Relative error of elliotsg function for each node selected

| No. of nodes | Elliotsg function | Relative error | Mean square error of relative error |
|--------------|------------------|----------------|-----------------------------------|
|              |                  | ZP031 | ZP032 | ZP033 | ZP034 |                  |
| 1            | 8.3832           | 8.5795 | 7.3783 | 8.4259 | 4.841097 | 5.032681 | -3.04668 | 5.21886 | 4.617436 |
| 2            | 8.503            | 8.1787 | 8.2194 | 7.9334 | 6.339327 | 3.053103 | 8.005656 | -0.93126 | 5.349446 |
| 3            | 7.5004           | 8.387 | 7.7015 | 8.3481 | -5.57398 | 2.676041 | 1.200277 | 4.247328 | 3.798385 |
| 4            | 8.3196           | 8.1721 | 8.2885 | 8.4058 | 4.045709 | 0.045174 | 8.913653 | 4.96786 | 5.488685 |
| 5            | 7.9459           | 8.4203 | 8.0035 | 8.4748 | -0.60782 | 3.083709 | 5.168658 | 5.829501 | 4.201236 |
| 6            | 7.8867           | 8.5316 | 7.9133 | 8.0636 | -1.36818 | 4.446275 | 3.9834 | 0.69462 | 3.081852 |
| 7            | 8.0463           | 8.2701 | 7.6085 | 7.551 | 0.627793 | 1.244918 | -0.02177 | -5.7065 | 2.937199 |
| 8            | 7.7209           | 8.44 | 7.3295 | 8.669 | -3.44169 | 3.324882 | -3.68793 | 8.254584 | 5.114661 |
| 9            | 8.0551           | 8.0621 | 8.2036 | 7.9246 | 0.737847 | -1.30148 | 7.798039 | -1.04115 | 4.004112 |
| 10           | 8.4612           | 8.1956 | 7.4611 | 8.3083 | 5.816572 | 0.332868 | -1.95866 | 3.750324 | 3.600159 |
| 11           | 8.4455           | 8.2263 | 7.4237 | 8.2682 | 5.620227 | 0.708706 | -2.45011 | 3.249573 | 3.487548 |
| 12           | 8.1396           | 7.6237 | 7.3754 | 8.0928 | 1.794612 | -6.66849 | -3.08479 | 1.059257 | 3.818618 |
| 13           | 7.7745           | 7.8591 | 7.7684 | 8.5052 | -2.77136 | -3.78666 | 2.079366 | 6.209123 | 4.0279 |
| 14           | 7.8683           | 7.4377 | 8.2082 | 8.0289 | -1.59829 | -8.94556 | 7.858484 | 0.261302 | 6.008361 |
| 15           | 8.0069           | 7.7363 | 8.0629 | 8.4604 | 0.135053 | -5.29001 | 5.949194 | 5.64968 | 4.881452 |
| 16           | 7.5064           | 7.9378 | 7.7054 | 8.0972 | -6.12425 | -2.82319 | 1.251525 | 1.114202 | 3.474356 |
| 17           | 8.6777           | 8.1739 | 8.5437 | 7.7321 | 8.399081 | 0.06721 | 12.26707 | -3.445 | 7.630499 |
| 18           | 7.3218           | 7.6277 | 7.9284 | 8.1774 | -8.43287 | -6.61953 | 4.181819 | 2.115703 | 5.850113 |
| Mean value   | 8.0335           | 8.1166 | 7.84019 | 8.1926 | 0.4678 | -0.6344 | 3.0226 | 2.3054 | 4.5207 |
consider the weight problem. If there are results of the authoritative evaluation in the past, people can easily take advantage of existing large amounts of data to train the network and then conduct the evaluation. In this way, the subjective evaluation of human factors can be eliminated, so it meets the requirement of the application of realistic evaluation, providing a new way of thinking for evaluation of teachers’ innovation and entrepreneurship competency in universities.

In this study, an evaluation method of teachers’ innovation and entrepreneurship competency based on artificial neural networks is established. However, neural networks have a dependence on the samples, and the approximation and application of the network model are closely related to the typicality of learning samples. Challenges are faced in selecting typical samples from the questions to form the learning sample set. Besides, more examples are required for further verification of the maturity of this method.

DECLARATIONS

Ethical Approval and Consent to participate: Approved.
Consent for publication: Approved.
Availability of supporting data: We can provide the data.

Table 15. Relative error of logsig function for each node selected

| No. of nodes | Logsig function | Relative error | Mean square error of relative error |
|--------------|-----------------|----------------|-----------------------------------|
|              |                 | ZP031   ZP032   ZP033   ZP034   |                                   |
| 1            | 8.5019          | 8.2325 | 7.6151 | 8.137 | 6.32557 | 0.784608 | 0.064953 | 1.611206 | 3.287425 |
| 2            | 8.4354          | 8.2011 | 7.5162 | 8.2351 | 5.493915 | 0.4002 | -1.23463 | 2.836235 | 3.158789 |
| 3            | 8.0542          | 8.1643 | 7.3952 | 8.2931 | 0.726592 | -0.05032 | -2.82461 | 3.560513 | 2.301419 |
| 4            | 8.0336          | 8.2692 | 7.8426 | 8.0491 | 0.468966 | 1.2339 | 3.054379 | 0.513551 | 1.683404 |
| 5            | 8.2045          | 8.2358 | 7.9212 | 8.3366 | 2.606258 | 0.825008 | 4.087209 | 4.103722 | 3.202305 |
| 6            | 7.9988          | 8.1047 | 7.4288 | 7.9882 | 0.033754 | -0.77996 | -2.38309 | -0.24694 | 1.259918 |
| 7            | 8.2039          | 7.8041 | 7.8825 | 7.9665 | 2.598754 | -4.45999 | 3.578678 | -0.51792 | 3.151197 |
| 8            | 8.3901          | 8.414  | 7.9921 | 7.8688 | 4.927389 | 3.006583 | 5.018858 | -1.73795 | 3.921993 |
| 9            | 8.3813          | 8.208  | 7.7716 | 8.1117 | 4.817335 | 0.484672 | 2.121415 | 1.295271 | 2.721202 |
| 10           | 8.2911          | 8.378  | 7.8078 | 7.9879 | 3.689286 | 2.56586 | 2.597095 | -0.25069 | 2.598183 |
| 11           | 8.0632          | 8.0965 | 7.9184 | 8.0423 | 0.839146 | -0.88034 | 4.050416 | 0.428635 | 1.215369 |
| 12           | 8.0901          | 8.0606 | 8.8789 | 7.8698 | 1.17556 | -1.31984 | 3.649636 | -1.72547 | 2.203463 |
| 13           | 8.2745          | 8.1079 | 7.7393 | 8.2623 | 3.481684 | -0.74078 | 1.696982 | 3.175897 | 2.531647 |
| 14           | 7.9337          | 8.3415 | 7.6615 | 8.2798 | -0.78039 | 2.119017 | 0.674664 | 3.394429 | 2.06619 |
| 15           | 8.3231          | 8.7818 | 7.6535 | 8.1902 | 4.089481 | -3.63118 | 0.569541 | 2.275544 | 2.975392 |
| 16           | 8.1359          | 8.1503 | 7.8123 | 8.0812 | 1.74834 | -0.22171 | 2.656226 | 0.914401 | 1.658125 |
| 17           | 8.5693          | 7.922  | 7.573  | 7.9902 | 7.168481 | -3.01662 | -0.48826 | -0.22197 | 3.897909 |
| 18           | 8.0273          | 8.1377 | 7.8299 | 8.0503 | 0.390178 | -0.37596 | 2.887496 | 0.528536 | 1.492529 |
| Mean value   | 8.2173          | 8.15   | 7.736  | 8.0967 | 2.766683 | -0.22538 | 1.654276 | 1.107611 | 2.568692 |
Table 16. Results of evaluation of BP neural network of teachers’ innovation and entrepreneurship competency in W university (self-evaluation, 34 people, 9-point scale)

| No. of teachers | Score of BP network | Score of AHP | Relative error | Rate of error (%) |
|-----------------|---------------------|-------------|----------------|------------------|
| ZP001           | 8.1712              | 8.1712      | 0.000036       | -0.000440        |
| ZP002           | 8.0611              | 8.0575      | 0.003574       | 0.044356         |
| ZP003           | 8.0532              | 8.0513      | 0.001856       | 0.023052         |
| ZP004           | 8.3818              | 8.3848      | -0.00302       | -0.036065        |
| ZP005           | 7.963               | 7.9579      | 0.005071       | 0.063723         |
| ZP006           | 8.2638              | 8.2613      | 0.002533       | 0.030661         |
| ZP007           | 8.6213              | 8.6254      | -0.00408       | -0.047395        |
| ZP008           | 7.032               | 7.0313      | 0.000717       | 0.010197         |
| ZP009           | 7.0729              | 7.0722      | 0.000683       | 0.009658         |
| ZP010           | 8.2503              | 8.2480      | 0.002346       | 0.028443         |
| ZP011           | 7.2156              | 7.2142      | 0.001402       | 0.019433         |
| ZP012           | 7.5978              | 7.5959      | 0.001936       | 0.025487         |
| ZP013           | 8.5381              | 8.5365      | 0.001617       | 0.018942         |
| ZP014           | 7.5844              | 7.5675      | 0.016874       | 0.222979         |
| ZP015           | 8.4885              | 8.4922      | -0.00368       | -0.043392        |
| ZP016           | 8.3839              | 8.3859      | -0.00201       | -0.024004        |
| ZP017           | 7.7434              | 7.7440      | -0.00055       | -0.007205        |
| ZP018           | 8.5579              | 8.5605      | -0.00256       | -0.029928        |
| ZP019           | 7.8127              | 7.8101      | 0.002621       | 0.033559         |
| ZP020           | 8.1842              | 8.1855      | -0.00132       | -0.016138        |
| ZP021           | 8.4226              | 8.4199      | 0.002697       | 0.032031         |
| ZP022           | 8.6066              | 8.6105      | -0.00388       | -0.045107        |
| ZP023           | 7.9602              | 7.9594      | 0.00077        | 0.009674         |
| ZP024           | 8.206               | 8.2110      | -0.00495       | -0.060309        |
| ZP025           | 7.2408              | 7.2414      | -0.00064       | -0.008851        |
| ZP026           | 8.1148              | 8.1245      | -0.00974       | -0.119920        |
| ZP027           | 8.3777              | 8.3790      | -0.00129       | -0.015407        |
| ZP028           | 8.4747              | 8.4766      | -0.00186       | -0.022001        |
| ZP029           | 7.8268              | 7.8277      | -0.00086       | -0.010999        |
| ZP030           | 7.9846              | 7.9826      | 0.002031       | 0.025442         |
| ZP031           | 7.9988              | 7.9961      | 0.002699       | 0.033753         |
| ZP032           | 8.1047              | 8.1684      | -0.06371       | -0.779955        |
| ZP033           | 7.4288              | 7.6102      | -0.18135       | -2.383091        |
| ZP034           | 7.9882              | 8.0080      | -0.01977       | -0.246941        |

**COMPETING INTERESTS**

There is no potential competing interests in our paper. And all authors have seen the manuscript and approved to submit to the journal. We confirm that the content of the manuscript has not been
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**AUTHOR’S CONTRIBUTIONS**

All authors take part in the discussion of the work described in this paper. These authors contributed equally to this work and should be considered co-first authors.
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