Evaluation of the innovation ability of engineering students based on entropy theory

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ABSTRACT: The quantitative evaluation of the innovative ability of engineering students is a new and complex undertaking. Using the four aspects of the understanding of theory, judgement, practical ability and research ability, outlined in this article is an innovation ability evaluation index system for engineering students. Furthermore, an empirical analysis is provided for a sample of engineering students using entropy theory and the co-ordination degree method. The research results show that the model for the evaluation of the innovative ability of engineering students is reasonable and effective.

INTRODUCTION

Innovative ability is a major source of social development. The cultivation of innovative consciousness and ability in higher education is not only necessary for social development, but also for education itself [1]. For engineering students, scientific research and engineering practical ability are the most direct and objective reflection of innovative consciousness and ability [2]. The practical teaching linked to the curriculum includes the graduation design and experiment courses. Currently, there exist many studies about college students' training and mode of training [3][4]. There is a consensus on some problems, but few were focused on the evaluation of the innovative ability of engineering students [5]. That is because the evaluation of innovative ability is a new and complex undertaking.

The traditional evaluation system emphasises examination scores. Research on the evaluation of college students' innovative abilities can inform education as to how to cultivate innovative ability. At the same time, innovative ability, which is an important index in evaluating students, will not only encourage the students to take part in innovative activities, but also inspire students who only care about grades. The evaluation of innovation ability can be helpful for college students in developing the spirit of innovation. This study combines the method of entropy and co-ordination degree to evaluate the innovative ability of engineering students [6].

THE EVALUATION INDEX SYSTEM

Principles for building an index system are as follows:

- Comprehensive and systematic: the concept of innovative ability is broad, with many aspects, i.e. it is comprehensive. The standard must be systematic and reflect its comprehensive characteristics. Each index should be well defined and fit well with other indexes, i.e. it should be organic.
- Easy access to data: although the choice of a statistical index is scientific, there are many options, some of which could restrict the application. Therefore, most of the set indicators should be obtained by way of investigation and observation.
- Concise and practical: the purpose of building the evaluation index system is to allow a complex problem to be evaluated to provide a comparative quantitative basis for evaluating training schemes. In establishing the index system, the selected indicators may not be completely comprehensive, else, it could make the index system very complex and cumbersome.
- The characteristics of engineering education: engineering education has the distinctive features of applicability and operability. Therefore, engineering students must have strong application and practical abilities, as reflected in the technical work of production and construction [7].

Building an Evaluation Index System

The cultivation of the innovative ability of engineering students includes the teaching, course experiments and the graduation project. The object of study of innovative ability is mainly the individual student. Therefore, the evaluation indexes and assessment should be congruent with the practical teaching content. Due to the comprehensive nature of innovation, a single index would be inadequate and, therefore, there should be multiple indexes, which evaluate innovation from multiple perspectives.

By considering the characteristics of engineering education, four aspects of innovation were chosen, viz. understanding of theory, judgment, practical ability and research ability. The *understanding of theory* involves a student's professional theory and knowledge. The *judgment* ability involves analytical ability. The *practical ability* concerns operational capability. The *research ability* reflects logical thinking and breadth of knowledge [8][9]. The index system is shown in Figure 1:

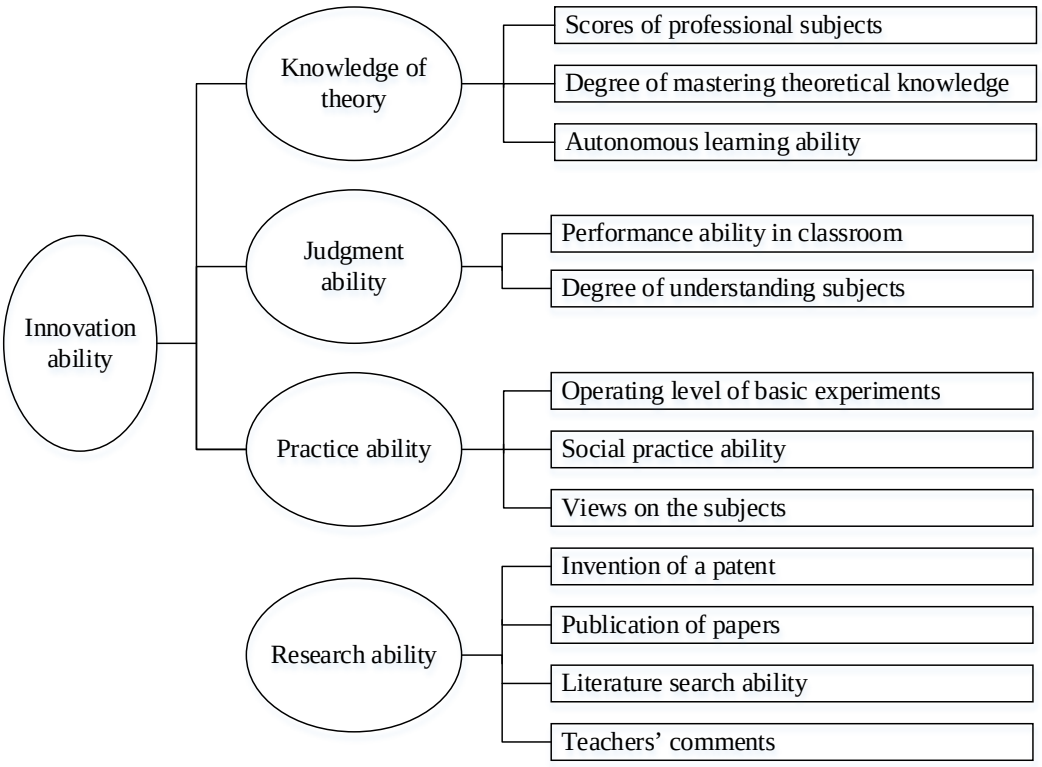

Figure 1: The evaluation index system for innovative ability.

BUILDING THE MODEL

Entropy value and co-ordination degree can be used to evaluate the innovative ability of a student [10].

A_i is the innovation ability of the student, W_j is the weight of the evaluation index *j*, and $V_i(j)$ is the co-ordination degree under the evaluation index. Therefore, the model can be represented as:

$$A_i = \sum_{j=1}^{n} W_j V_i(j) \tag{1}$$

Entropy Weights

Entropy is a concept from physics, specifically thermodynamics [11]. Later, the American scholar C.E. Shannon developed the concept further [12], leading to:

$$H(x) = -C\sum_{i=1}^{n} p(x_i)\lg p(x_i) \tag{2}$$

In Formula (2), x_i is an event and $p(x_i)$ is the probability of its occurrence. As a result, there is a relationship between entropy and the degree of order. The greater the entropy, the lower the order and the greater the uncertainty. So entropy can be used to determine the weight of each index.

Each index is different, and so they cannot be directly compared. Hence, it is necessary to define the standardised index data:

$$*x_i = \frac{\left|(x_{ij} - \bar{x}_j)\right|}{s_j} \tag{3}$$

where x_{ij} is the indicator value j for the i^{th} student, $\bar{x}_j$ is the average and s_j is the standard deviation. Therefore,

$$p_{ij} = \frac{*x_i}{\sum_{i=1}^{m} *x_i} \tag{4}$$

The entropy for each index is given by:

$$e_j = -k\sum_{i=1}^{m} p_{ij} \lg(p_{ij}) \tag{5}$$

Using the adjustment coefficient,

$$k = \frac{1}{\ln m}, \tag{6}$$

the entropy value of each index becomes:

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \lg(p_{ij}) \tag{7}$$

The difference coefficient for each index $g_j = 1 - e_j$ noting that $0 \le e_j \le 1$. A greater g_j, implies more importance. So, the weight coefficient of each index is:

$$w_j = \frac{g_j}{\sum_{j=1}^{n} g_j} \tag{8}$$

This improved entropy method to determine the index weight does not require any subjective information, and is completely objective.

The Determination of Index Values

The determination of individual indexes using the co-ordination degree function is given by:

$$V_A(v_i) = \begin{cases} 1 & x_i = \mathrm{a}_i \\ \dfrac{x_i}{a_i} + \dfrac{x_i - b_i}{a_i - b_i} & x_i \prec \mathrm{a}_i \end{cases} \tag{9}$$

where a_i is the target value and b_i is the base value. In practice, b_i is the average value for an individual. The efficacy function has two parts; $\frac{x_i}{a_i}$ reflects the closeness of the present value to the target value and $\frac{x_i - b_i}{a_i - b_i}$ is the change of the evaluation index, which may be positive or negative [13][14].

EXAMPLE ANALYSIS

The index weights for ten engineering students are shown in Table 1. The index values of innovative ability were obtained using Formula (9), and the results are shown in Table 2.

Table 1: Index weightings.

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
0.101	0.076	0.081	0.085	0.103	0.102	0.131	0.118	0.096	0.042	0.065

Table 2: The index values of innovative ability.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
P1	1.00	0.59	0.66	0.39	0.51	0.35	1.00	0.95	1.00	0.46
P2	1.00	0.72	0.63	0.29	0.49	0.31	0.94	0.81	1.00	0.51
P3	0.97	0.75	0.61	0.61	0.53	0.42	0.95	0.76	1.00	0.63
P4	0.78	0.79	0.75	0.85	0.48	0.86	1.00	0.77	0.91	0.75
P5	0.81	0.81	0.91	0.76	0.41	0.85	1.00	0.72	0.85	0.44
P6	0.97	0.66	0.60	0.50	0.50	0.86	0.85	0.75	0.91	0.48
P7	1.00	0.75	0.58	0.58	0.57	0.76	0.80	0.85	0.85	0.51
P8	1.00	0.45	0.59	0.65	0.91	0.81	0.76	0.66	0.76	0.50
P9	0.77	0.39	0.62	0.51	0.81	0.44	0.81	0.55	0.76	0.89
P10	0.85	0.42	0.76	0.57	0.76	0.51	0.69	0.44	0.81	0.50
P11	0.45	0.55	0.44	0.35	0.81	0.47	0.65	0.51	0.94	0.76

Using the co-ordinating degree and weight of each sample, using Formula (1), the value of innovative ability can be calculated. The results are shown in Figure 2.

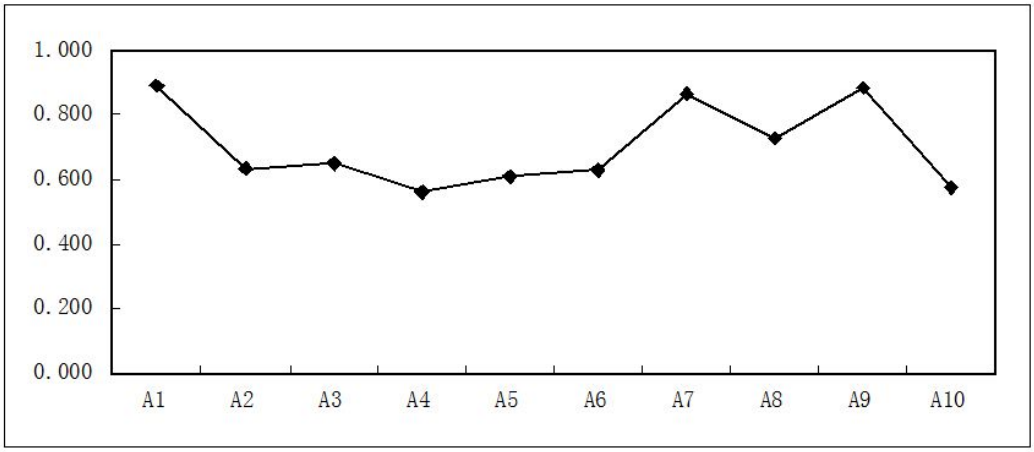

Figure 2: Innovation ability of a sample of engineering students.

CONCLUSIONS

Building an evaluation system of innovation ability for engineering students can promote the cultivation of innovative ability even with limited teaching resources. Proposed in this study is an evaluation system based on four aspects of innovation, viz. understanding of theory, judgment, practical ability and research ability.

The method of entropy value and co-ordination degree were used to provide an empirical analysis of a sample of engineering students. The results show that the evaluation model is reasonable and, in general, effective. However, gathering statistical data is difficult, which leads to the indexes being imperfect. The empirical study was based on limited data. So, further research is required on the evaluation model of innovative ability of engineering students.

Cultivating students' innovative ability is one of the goals of higher education. A student's creative abilities are influenced by many factors, such as the student himself (or herself), family, teachers, schools and social environment. A change of external environment changes its entropy. Therefore, the entropy theory for the evaluation of students' innovative ability can provide a scientific tool.

In this study, entropy theory was used in the research carried out on students' innovative ability. On the one hand, in addition to the wide usage of the principal component analysis (PCA) method, entropy theory is a scientific and

operational method that can further strengthen the objectivity of studies. On the other hand, entropy theory has provided a quantitative evaluation, avoiding the defects of subjective evaluation.

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