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Using factor analysis to train students of an engineering major to innovate

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ABSTRACT: Innovation is a great power for survival and development. However, the innovative ability of human beings is not endowed, and it needs continuous training. China's Challenge Cup engineering project is a good stage for high-tech talent, but it is also an important platform for innovation. By means of a questionnaire survey and deep interviews, reported in this article is a study into participants of Liaoning University of Technology in a Challenge Cup engineering project. The aim was to understand the elements that influence the innovative ability of the student participants. Factor analysis was used to determine the affecting factors and their relative significance. Problems that exist in the process of student participation in the project were pointed out. Finally, reform measures are put forward as follows: the Challenge Cup should be better publicised, include innovation-oriented activities into the curriculum, strengthen the cultivation of students' teams, and establish the funding and rewards to support students' innovative ability in the Challenge Cup.

INTRODUCTION

Innovation is important for national development. The competition between nations is especially competition between the creative components of nations. However, innovative ability is not innate, and must be developed continuously. At present, universities are paying more attention to developing the innovative ability of engineering students. However, Chinese universities have not done enough in this area, and the development of students' innovative ability should be further cultivated in students with an engineering major [1].

The Challenge Cup is a national competition of academic projects by university students. Engineering projects adhere to the tenet of *advocate science, the pursuit of knowledge, study diligently and innovate to meet the challenge* [2].

It aims to improve engineering students' innovation ability and research new problems using new methods. Technological innovation driven by the Challenge Cup engineering project could stimulate the participants in innovative and technological achievements. Thus, the Challenge Cup is considered, in this article, as a platform for analysing the impact of the training of innovative ability, by universities, of students with an engineering major. Meanwhile, new ways can be explored to improve engineering students' innovative ability, based on the Challenge Cup.

FACTOR ANALYSIS METHOD

The factor analysis method (FAM) is used to resolve issues of index overlap in a multi-index system [3]. This method reassembles the original relevant indicators into a new, smaller group of independent indicators. Meanwhile, the new group retains the information of the original indicators. The few principal components, which have the largest variance are selected first, and weighted, to produce the correct evaluation values.

Given a data source, the indicators and principal component coefficient matrix are determined. Suppose there are *m* indicators and *n* factors, then:

$$\begin{cases} X_1 = a_{11}F_1 + a_{12}F_2 + \cdots + a_{1n}F_n + \zeta_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \cdots + a_{2n}F_n + \zeta_2 \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ X_m = a_{m1}F_1 + a_{m2}F_2 + \cdots + a_{mn}F_n + \zeta_m \end{cases} \qquad (1)$$

where, X = (X_1, X_2... X_m) is an observed random vector; a_{ij} is the factor weighting; F_i is a common factor of X; and ε_i is the special factor of X_i. In principal component analysis q < m principal factors are selected to maintain the original information as much as possible. Each principal factor can be expressed as a linear combination of the variables. Then, the value of each of the main factors can be calculated using the observed variables [4].

IMPACT OF THE CHALLENGE CUP ENGINEERING PROJECT ON THE INNOVATIVE ABILITY OF ENGINEERING MAJOR STUDENTS

A questionnaire study was conducted of a sample of engineering major students at Liaoning University of Technology. In total, 1,000 questionnaires were distributed, and 930 or 93% returned. The 930 returned questionnaires were all valid. Analysis of the results revealed that the main factors, which affect the innovative ability of engineering students in the project were: X_1 - participation in the Challenge Cup engineering project; X_2 - future development; X_3 - Challenge Cup spirit; X_4 - results of the Challenge Cup engineering project; X_5 - business conditions; X_6 - teamwork; X_7 - value of the application and practical significance; X_8 - practical ability during the project; X_9 - teachers' guidance; X_{10} - feasibility and innovation; X_{11} - importance of the participants; X_{12} - attitude towards finishing and word processing capability; X_{13} - support from senior students; X_{14} - awareness of innovation and feasibility in the choice of topic. The details are shown in Table 1.

Table 1: Analysis on factors affecting the engineering students' innovative ability.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
Great emphasis	23.22	18.16	29.46	12.80	22.27	20.90	11.40	36.10	20.90	22.50	25.60	28.20	24.60	40.40
Some emphasis	33.21	45.10	32.52	20.56	33.25	37.20	30.40	18.40	31.20	25.60	21.40	18.60	23.50	18.50
General importance	27.53	17.60	22.89	35.33	8.63	25.60	32.50	19.50	22.80	17.30	11.20	22.50	16.50	23.80
Less emphasis	6.21	11.20	12.33	8.56	22.30	11.80	10.40	22.80	16.50	11.20	22.30	15.90	22.30	6.90
Downplayed	9.33	5.44	2.65	10.25	11.25	4.50	14.50	3.20	8.60	21.20	14.30	11.30	11.60	8.60
No answer	0.50	2.50	0.33	12.50	2.30	0	0.80	0	0	2.20	5.20	3.50	1.50	1.80
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: The actual number of surveys handed out was 1,000. The number of valid answers to the questionnaire was 930.

The 14 fixed order variables in Table 1 would be transformed into fixed pitch variables. The usual practice is to consider the various codes as the value of these fixed order variables. Supposing that,

$$X_i \begin{cases} 1 & \text{The } i^{th} \text{ is great emphasis} \\ 2 & \text{The } i^{th} \text{ some emphasis} \\ 3 & \text{The } i^{th} \text{ general importance} \\ 4 & \text{The } i^{th} \text{ less emphasis} \\ 5 & \text{The } i^{th} \text{ downplayed} \\ 6 & \text{The } i^{th} \text{ no answer} \end{cases}$$

First, the correlation matrix of variables is determined and, then, characteristic values and eigenvectors of this matrix are calculated. Then, a factor loading matrix would be developed and a varimax orthogonal rotation performed. The final results matrix is shown in Table 2.

Table 2: Orthogonal factors.

	Component			Extraction
	1	2	3	
X_1	0.810	0.385	0.416	0.977
X_2	0.645	0.717	0.100	0.940
X_3	0.576	0.509	0.600	0.951
X_4	0.927	-0.299	0.145	0.970
X_5	0.148	0.952	0.256	0.994
X_6	0.755	0.541	0.340	0.978

X_7	0.921	0.256	0.112	0.925
X_8	0.089	0.375	0.895	0.949
X_9	0.648	0.618	0.424	0.982
X_{10}	0.451	0.574	0.390	0.684
X_{11}	-0.132	0.777	0.607	0.989
X_{12}	0.363	0.278	0.884	0.990
X_{13}	0.196	0.709	0.635	0.945
X_{14}	0.315	0.120	0.898	0.920
Cumulative (%)	49.274	65.392	74.246	

Note: the joint degree is to describe the contribution of total variance towards some indicator from all the main factors.

The 14 indicators are divided into three categories according to the loadings and the main factors named as below.

Based on the impacts of the Challenge Cup engineering project on the innovative ability of engineering students, the cumulative variance contribution of the main factors is greater than or equal to 70%. All data were processed using SPSS 19.0 software.

The correlation matrix of variables was found using SPSS 19.0. First, one needs to precede as per the three steps above and, then, by using the factors in the analysis of the questionnaire, the cumulative variance contribution of the main factor is 74.25%, which reaches the level set in the quantitative analysis of $\geq$ 70%. The situation of the joint degree, for which a description of the information of some indicator is reflected by all the main factors, is similar to that of the main factor.

The first main factor F_1 has larger loadings for X_1, X_4, X_6 and X_7. These deal with attitude, the result and the work and the impact of the project on participants. Thus, F_1 can be named the *value factor* of the Challenge Cup engineering project. The second main factor F_2 has larger loadings for X_2, X_5, X_{11} and X_{13}, which reflect the business conditions, and therefore F_2 is the *entrepreneurial factor*. The third main factor F_3 has greater loadings for X_8, X_{12} and X_{14}, which relate to practical ability, the attitude towards finishing, word processing capability, and the awareness of innovation and feasibility in the choice of topic. Thus, F_3 can be named the *capacity factor*. The value factor, the entrepreneurial factor, and the capacity factor are, in order, the three main factors for participants in the Challenge Cup engineering project.

Among the 14 X_i factors, attitude to participation, the results and the value of the work are the primary factors. This is followed by the entrepreneurial conditions and, then, practical ability, the attitude towards finishing, word processing capability and the awareness of innovation and feasibility in the choice of topic.

PROBLEMS IN TRAINING ENGINEERING STUDENTS TO INNOVATE

From the analysis of the questionnaire results using SPSS 19.0, the following problems were identified.

Low participation rate: of the 930 students, 25% participated in the Challenge Cup, and the other 75% did not. Among those, 91% are willing to participate next year. However, some engineering students limit their topics just to the major they study and some topics are not creative enough, since conclusions are available in textbooks. So, it is challenging for them to address a topic with substantial content.

In addition, they do not have enough practical knowledge and engineering background to select an appropriate and challenging topic yet. These often cause them to either not be able to hand in their work on time or fail in the first round of the engineering project. In short, students are very interested in the Challenge Cup engineering project, but their limited knowledge holds them back from participation.

Limited ways to acquire information: 73.7% of the students contacted their product suppliers on-line and 26.3% contacted suppliers in other ways. Of the students, 45% heard about the Challenge Cup engineering project through the University's promotion; 28.8% heard of it from their teachers or from fellow students; and 26.2% of the students had not heard about the Challenge Cup project at all.

Building a team is hard: because individual students have different goals and backgrounds, there are some difficulties in finding partners and building an effective team to join the project. From the analysis, most of the students look for teammates from among their fellow classmates. Of the students, 58.3% believe that consensus among the team members is most important. However, in this way, it is difficult to build a multidisciplinary team, which often leads to a narrow view of their topic.

Tutors' guidance is imperfect: among the students who participated in the Challenge Cup engineering project, 6.3% received no help or guidance from their advisors; 36.3% of them had mentorship assistance one or two times; 46.3% of them received guidance three or four times; and only 11.3% received help from their tutors more than four times. Of the 50 university teachers involved in the survey, 90% said that they provided technical guidance and expertise; 8%

considered that they shared some experiences; and only 2% of the teachers said they offered a lot of guidance to their students.

SUGGESTIONS FOR IMPROVING ENGINEERING STUDENTS' INNOVATIVE ABILITY

Set clear goals and values: cultivation of innovative talent is a process of seeking truth from facts, in which students are expected to continuously solve difficult problems to achieve their goals. The Challenge Cup engineering project aims to *...guide and encourage engineering students to seek truth, be assiduous and innovative, to achieve more for both their professional and personal goals*. Therefore, the ideology that *...participation and enjoyment from the process in the project is more important than results, and the project aims to promote the cultivation of innovative talents* should be established. Positive life values for engineering students should be developed, as well as a correct righteousness and ethical evaluation criteria applied [5]. Thus, they could regulate their innovative behaviours using these evaluation criteria.

Increase knowledge of the Challenge Cup: through various channels, such as radio, and Blackboard (product of Blackboard Inc.) advertisements, students could learn more about the time and purpose of the Challenge Cup engineering project. This should stress the important role of the Challenge Cup engineering project in improving their innovative ability. Students should be assisted in contacting product suppliers and obtaining technical support, and it should be made easier for students to join the project.

Integrate curricula teaching with engineering projects: innovation-oriented activities provide a platform for cultivating engineering students' innovative ability. Through participation in innovation-oriented activities, the students could improve their ability to use statistical analysis methods and to write scientific research papers. In daily teaching, teachers could cover more engineering knowledge related to the project, and they could combine theory and practice. Thus, the development of the students' abilities for analysing, solving problems, critical thinking and word processing skills could be accelerated. In addition, teachers should be encouraged to set up specific courses, to systematically teach students the knowledge and methods related to innovation-oriented activities to develop their innovative skills and abilities [6].

Strengthen team building: universities should select and train a group of responsible teachers to be involved in guiding students in the Challenge Cup engineering project. Teachers should give guidance on key milestones, such as selecting the topic, researching the context, adopting scientific methods and writing the report. Students' team-building should be enhanced by putting students with different strengths and backgrounds together to build an effective, multidisciplinary team. During the project, team members could learn from each other and research the topic together, which will help to create a productive environment for innovation [7].

Establishment of a guaranteed funding system: first, the guarantee system for funding should be improved. It should provide adequate funding for students' innovative activities through the establishment of the fund, the university's financial support and sponsorships [8]. Second, sufficient test sites should be provided. A variety of laboratories and equipment should be available for innovative activities. Third, the mechanism of evaluation and encouragement should be perfected. Benefits, such as scholarships could be provided to the engineering students who gained awards in the Challenge Cup engineering project. Award-winning advisors should be subsidised for their work and/or get a bonus. All participants should be recognised for their efforts on the project. They could be given some rewards in order to encourage more teachers and students to involve themselves in innovative activities.

CONCLUSION

Innovation is a driving force behind a nation's prosperity. The Challenge Cup engineering project is a comprehensive platform by which to develop engineering students' innovative abilities. Therefore, the Challenge Cup engineering project is a great opportunity to carry out comprehensive innovative activities for enhancing engineering students' creative abilities, and overall quality, as well as for training more talent with innovative skills.

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