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Investigation of Critical Thinking Tendency of Engineering Students and Analysis of Teaching Countermeasures

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Abstract

“New Engineering” construction puts forward higher requirements for the critical thinking ability of engineering talents in the future. With “California Critical Thinking Disposition Inventory Chinese Revision”, the critical thinking tendency of engineering majors in local engineering colleges was investigated and analyzed. The results showed that the critical thinking level of the engineering students was obviously lower. According to the findings and teaching practice, this paper gives some teaching countermeasures to strengthen the cultivation of critical thinking of engineering students.

Keywords: Critical Thinking; Engineering College Students; Investigation; Teaching Countermeasures

1 BACKGROUND OF INVESTIGATION

“Critical thinking is purposeful, self-regulatory judgment.” [1] As a unique way of thinking and a basic ability of human beings, critical thinking is the premise of thought independence and idea innovation. Over the years, the cultivation of critical thinking has attracted more and more attention in the western education field, many countries, such as the United States, Britain, Australia, Canada and so on, have listed it as one of the goals of higher education. In these countries, critical thinking is recognized and cultivated as a kind of comprehensive thinking, and regarded as a part of learners' personality growth and self-improvement. Now in China, critical thinking has gradually become a part of quality education and innovation education. As the basic quality of innovative talents in the new era, it has attracted more and more attention of educators. The cultivation of critical thinking ability has gradually become one of the hot issues in education research.

In the field of higher education in China, engineering is one of the most popular subjects, both the number of engineering universities and the number of engineering students in China are in the forefront of the world. In the face of a large number of engineering students, if we want to turn the advantages in quantity into the advantages in human resources quality and even the advantages in national comprehensive competitiveness, it is necessary to improve the quality of engineering education. In 2017, 612 state-level new engineering research and practice projects were officially recognized by the Ministry of Education, which means that the construction of “New Engineering” projects that have attracted much attention from higher education circles has entered the implementation stage. “New Engineering” emphasizes the practicability, intersection and comprehensiveness of the discipline, and its core goal is to produce great engineers, that is, those who apply the principles of nature to make great innovations. Therefore, the cultivation of creative thinking and critical thinking is very important to improve the quality of engineering education. Critical thinking focuses on “*breaking*”, while creative thinking focuses on “*establishing*” [2]. Critical thinking is the power and foundation of creative thinking. Without criticism, there is no creation. Only when we are good at criticizing the limitations and mistakes of others and do not blindly follow the authority, can we innovate; only when we are good at criticizing our own limitations and mistakes and do not stand on our own feet, can we

grow up. In the “New Engineering” construction action line (“Tianda Line”), it is clearly proposed to strengthen the critical thinking of engineering students [3]. In order to fully understand the status quo of critical thinking of engineering students and provide reference for the cultivation of critical thinking of engineering students, we have done the following research.

2. RESEARCH PROCESS

2.1. Research Purpose

This paper explores the overall status and different characteristics of critical thinking of engineering students, including two aspects: one is the descriptive analysis of the total score of critical thinking tendency of engineering students and the scores of each dimension; the other one is the difference of critical thinking tendency of engineering students in gender, learning level and other aspects as well as the analysis of the difference with other majors.

2.2. Research Tool

The questionnaire used in the survey is the Chinese version of “*California Critical Thinking Disposition Inventory*” (CCTDI) [4], which is used to measure the personality tendency of critical thinking. This questionnaire is used to measure the tendency of critical thinking personality. It is suitable for college students and middle school students. It has high reliability and validity. CCTDI divides the personality tendency of critical thinking into seven dimensions, that are truth seeking (T), open mindedness (O), analyticity (A), systematism (S), self-confidence (C), inquisitiveness (I) and maturity (M). Each dimension includes several statements as test items. Likert 6 rating method was adopted for the questionnaire scale, with 7 dimensions corresponding to 7 subscales, and each subscale had 10 items, with a total of 70 items, so as to distinguish the strength and weakness of the subjects in critical thinking emotional tendency. The score of each sub scale is 10-60, and the score less than or equal to 30 indicates that there is no corresponding critical thinking tendency, the score greater than 50 indicates that there is a corresponding strong critical thinking tendency. The total score of this test is 70-420, a score greater than 280 points indicates a positive critical thinking personality, and a score greater than 350 points indicates a strong tendency to critical thinking.

2.3. Research Object

Considering that the research results should provide reference for the cultivation of critical thinking of engineering students, and relevant foreign research shows that more than two-thirds of critical thinking during the university period was obtained in the first year, so we targeted the survey object at the freshmen majoring in engineering of local engineering colleges, whose major involves civil engineering, machinery manufacturing, Internet of things, electricity, applied physics, etc. In order to form a contrast, a small number of senior students and some science and arts students were also investigated. The samples were determined by stratified random sampling method. A total of 500 questionnaires were distributed, 494 were recovered, 486 were valid, and the effective rate was 98.4%. Among them, 348 were in engineering (63% for boys and 37% for girls), 63 were in science (60% for boys and 40% for girls), and 75 were in arts (39% for boys and 61% for girls).

2.4 Data Processing and Analysis

In order to achieve better results, the order of questions in the original questionnaire was scrambled, and the questionnaires were classified and summarized after recovery. The data were input into the EXCEL table and then rearranged in the order of the original questionnaires. SPSS was used for collation and analysis, including descriptive statistical analysis and difference test analysis.

3 SURVEY RESULTS

3.1 Critical Thinking Status of Engineering Students

3.1.1 Mean and Standard Deviation of the Total Score

The total score distribution of critical thinking tendency of engineering students is shown in figure 1.

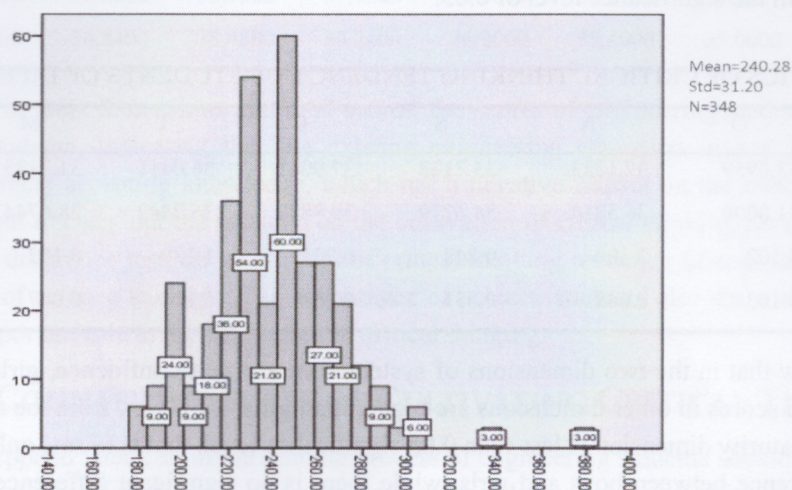


FIGURE 1 HISTOGRAM OF FREQUENCY DISTRIBUTION OF TOTAL CRITICAL THINKING TENDENCY OF ENGINEERING STUDENTS

can be seen from the figure that the mean score and standard deviation of the total score of critical thinking tendency of engineering students were 240.28 and 31.20, which were significantly different from the cut-off point of positive critical thinking tendency of 280. More than 60% of the students scored between 220 and 270 points. 30 students with 280 points or above, accounting for 8.62%. Only 3 people with a score above 350, accounting for 0.86%. From this result, the critical thinking characteristics of engineering students are generally weak, with less than one in ten students with positive critical thinking character, and those with strong critical thinking ability are even more rare.

1.2 Mean and Standard Deviation of Sub Scales

Table 1 lists the scores of each subscale of critical thinking tendency of engineering students.

TABLE 1. DESCRIPTIVE STATISTICS OF ALL DIMENSIONS OF CRITICAL THINKING TENDENCY OF ENGINEERING STUDENTS

	T	O	A	S	C	I	M
mean	31.8276	32.2190	36.9224	34.0517	38.6379	35.9310	30.5862
Std	7.67749	6.68366	6.02913	5.07996	7.46050	6.13575	7.96958
≤30	40.5%	44.0%	12.9%	19.8%	11.2%	17.2%	50.0%
>50	0.8%	4.3%	1.7%	0.8%	11.2%	3.4%	1.7%

As can be seen from the above analysis, the mean value of all the scales was between 30 and 40 points, among which the self-confidence score of critical thinking was 38.679, and 11.2% of the scales were greater than 50 points, which were the highest among all the sub-scales. The score of maturity was 30.5862, the lowest among all subscales. Meanwhile, the proportion of students who scored less than or equal to 30 points in this dimension reached 50%, indicating that half of the students do not have the tendency of critical thinking in this aspect. The other dimensions are ranked from highest to lowest in terms of analyticity, inquisitiveness, systematism, open mindedness, and the truth seeking. This result shows that students have a certain recognition of their own rational analysis ability, have a willingness to think critically and have a certain analytical ability, but blindly worship textbooks and teachers, and lack confidence in reflection and questioning. At the same time, due to the influence of the educational environment, the corresponding external training stimulation is seriously insufficient, resulting in low cognitive maturity.

1.3 Gender Differences

Table 2 lists the total scores of boys' and girls' critical thinking tendency and the scores of each sub scale, and makes

the mean difference test with the significance level of 0.05.

TABLE 2 SCORE STATISTICS OF CRITICAL THINKING TENDENCY OF STUDENTS OF DIFFERENT GENDERS

	T	O	A	S	C	I	M	TOTAL
boy	31.8356	33.0959	37.1233	33.7123	37.9041	36.0411	31.7123	241.4247
girl	31.8140	31.0000	36.5814	34.6279	39.8837	35.7442	28.6744	238.3256
F	1.061	0.102	2.100	0.848	0.735	1.230	0.102	0.597
Sig.	0.988	0.103	0.642	0.351	0.169	0.803	0.047	0.609

The results in Table 2 show that in the two dimensions of systematism and self-confidence, girls' score higher than boys', boys' total score and scores in other dimensions are higher than girls. However, from the mean difference test results, only sig value of maturity dimension is less than 0.05 significance level, that is to say, only in this dimension, there is a significant difference between boys and girls, while there is no significant difference between boys and girls in other dimensions and total scores. On the one hand, this result is related to the gender composition of engineering students. In most engineering majors, the proportion of male students is more than 70%, and female students are a vulnerable group. On the other hand, because of the inborn gender differences, boys and girls have different personalities, and girls are indeed inferior to boys in practical ability, innovation ability and open mind.

3.1.4 Differences between Junior College Students and Undergraduates

Table 3 lists the total score of critical thinking tendency and the test results of scores and mean differences of each sub scale.

TABLE 3 SCORE STATISTICS OF CRITICAL THINKING TENDENCY OF STUDENTS AT DIFFERENT LEARNING LEVELS

	T	O	A	S	C	I	M	TOTAL
Junior College Student	30.5814	31.6628	36.3023	33.0233	37.9419	35.1395	29.8140	234.4651
Undergraduate	35.4000	35.2000	38.7000	37.0000	40.6333	38.2000	32.8000	256.9333
F	0.019	2.128	0.177	1.782	1.731	1.292	0.598	1.229
Sig.	0.005	0.085	0.038	0.000	0.012	0.258	0.056	0.000

It can be seen from Table 3 that there was no significant difference between junior college students and undergraduates in the four dimensions of truth seeking, open mindedness, inquisitiveness and maturity, while in the three dimensions of analyticity, systematism, self-confidence and the total score, the scores of undergraduates were significantly higher than that of College students. Since the entrance scores of the junior college students were significantly lower than that of the undergraduates, this indicates that the students with excellent grades are more confident in thinking, have deeper knowledge accumulation and stronger ability to analyze and solve problems.

3.2 Analysis of Differences between Engineering Students and Other Majors

Table 4 shows the comparison of the scores and total scores of each sub scale between engineering students and other categories of students, and tests the mean difference between the total scores of engineering students and those of science students and arts students.

TABLE 4 SCORE STATISTICS OF CRITICAL THINKING TENDENCY OF STUDENTS OF DIFFERENT MAJORS

	T	O	A	S	C	I	M	TOTAL	Sig.
Engineering	31.8276	32.2190	36.9224	34.0517	38.6379	35.9310	30.5862	240.2759	

Science	35.3016	33.4286	38.7302	37.1905	41.3016	37.4762	30.4127	253.8413	0.013
Arts	33.0800	34.8400	38.4800	36.2400	36.2000	37.4000	35.0000	251.2400	0.095

Table 4 shows that in most dimensions and total scores, the scores of engineering students are lower than those of science and arts students, indicating that the existing engineering education makes students develop the inert psychology of passively accepting knowledge, which has a negative impact on the cultivation of critical thinking. Therefore, it is urgent to carry out the research on the cultivation of critical thinking for engineering students. From the results of mean difference test, the total score of critical thinking tendency of engineering students is obviously different from that of science students. The advantages of science students also show that the training of science courses plays an important role in the cultivation of critical thinking.

4 TEACHING COUNTERMEASURES OF CULTIVATING CRITICAL THINKING

Engineering needs applied talent, so in the training process of engineering students should not only instill knowledge to students, but also improve students in knowledge, methods, ideas, ways of thinking and other aspects, especially the cultivation of thinking will benefit students for a lifetime.

4.1 Combination of Cultivation of Critical Thinking and Teaching Reform Research

The traditional engineering education has a serious tendency of exam-oriented education. The teachers explain knowledge with "full lecture", but seldom guide students to think about problems actively. In practice, teachers train problem-solving methods more from the operational level, but less from the thinking level. Recent years, teaching reform in the field of engineering education is dynamic, but more is the reform of teaching method, teaching resource construction, the cultivation of student's thinking is neglected for a long time. Few people are standing in the perspective of psychology, pedagogy to deeply examines students' need, also very few people are standing in the thinking subject knowledge to consider the content and structure of subject knowledge. Therefore, in order to meet the requirements of "New Engineering" and improve students' critical thinking ability, educators must pay attention to the cultivation of thinking in the teaching reform, take the cultivation of critical thinking as one of the teaching objectives, integrate the training of thinking into all aspects of teaching, and find effective ways to improve students' critical thinking ability through teaching practice.

4.2 Combination of Cultivation of Critical Thinking and Subject Teaching

Foreign universities are more inclined to combine the cultivation of critical thinking with the teaching of specific subjects. With subject content as the carrier, systematic training is gradually carried out through course teaching to continuously strengthen the training of critical thinking of college students. This makes the quality education in the United States come true, which is what China's current higher education lacks and needs to learn. For engineering students, it is especially important to combine the cultivation of critical thinking with the teaching of basic courses of mathematics and physics. On the one hand, these courses are the important foundation of students' follow-up courses, not only the foundation of knowledge structure, but also the foundation of thinking training and training. On the other hand, science thinking involves many aspects of thinking training, such as logical reasoning, deductive judgment, etc., which is of great benefit to the cultivation of students' critical thinking.

Of course, the cultivation of critical thinking poses a great challenge to teachers. It requires teachers to subvert the "full-scale" teaching mode and give the stage in class to the students. It requires professional teachers to study the theory and practice of critical thinking deeply, and find out the organic connection between critical thinking and subject teaching.

4.3 Combination of Cultivation of Critical Thinking and Practical Teaching

Related studies have shown that cultivating mature critical thinking needs a long-term process, from the lack of the consciousness of reflection and skills, to recognize the lack of rational thinking method, and then to learn the skill of critical thinking, and then apply the skills of learning to naturally to life, finally makes critical thinking habit [5]. This indicates that students only have critical awareness and skills but cannot guarantee to apply these skills, they

need to practice in practice. Only through application can the value of critical thinking be reflected and constantly improved, and students themselves can finally grow into a real critical thinker.

The training of new engineering talents needs new knowledge, including constructing new knowledge system and curriculum system. Different from other majors, there are many practical courses in the training program of engineering major. We should give full play to the role of practical courses and make them a powerful way to cultivate critical thinking. In practice, there are many opportunities to find problems. After finding problems, students will reflect on the problems in rational thinking and make corrections. So students should be given more opportunities to find and correct mistakes, which is a process of critical thinking training. After a long-term training, critical thinking can become a habit and truly improve the skills of critical thinking.

4.4 Combination of Cultivation of Critical Thinking and Campus Culture Construction

The formation of critical thinking is a long-term process, which needs a long-term experience. It is necessary to form a school environment, social environment and family environment conducive to critical spiritual growth, which is very important to develop students' critical thinking. Campus is the inheritance place of human excellent culture and the gathering place of innovation, the campus culture with innovative characteristics is conducive to activating critical thinking and exerting the function of moistening things silently and continuously.

Campus activities in colleges are rich and colorful, special reports, symposiums, social practices, club activities and other hidden courses can be the way to cultivate students' critical thinking. Teachers can design related activities according to the characteristics of engineering students and the content of courses. Through the debate competition, speech competition, research, skills competition and other activities, students can improve their ability to solve practical problems by comprehensively applying the theoretical knowledge and thinking skills they have learned, so as to urge them to reflect on and internalize the knowledge they have learned. These meaningful activities can finally improve students' ability to solve problems comprehensively and improve their level of critical thinking.

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