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The effect of teaching reform of a mechanics of materials course on the abilities of students in engineering application and innovation

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ABSTRACT: Mechanics of materials is a basic professional course for engineering college and university students, and is also a course highly involved in engineering practice for students. It plays a key role in the cultivation of students' engineering application and innovation abilities. In order to better cultivate engineering application-oriented talents for employers, Jiangxi University of Science and Technology has attempted to reform the teaching of the *Mechanics of Materials* course in recent years. The teaching reform was comprehensive, including implementing reform in theoretical teaching, experimental teaching, as well as extracurricular scientific innovation activities and various competitions, so as to gradually cultivate students' engineering application and innovation abilities. By comparing the effects of teaching in two different college classes before and after teaching reform, it was found that students' engineering application and innovation abilities were improved significantly after the implementation of the teaching reform.

INTRODUCTION

With the rapid advancement of science, engineering and technology in China, employers have increasingly demanded innovation and strong engineering application abilities from college and university graduates [1]. Therefore, the cultivation of talents with such abilities is required in higher education for meeting the needs of an innovative society and its economic development [2][3]. Mechanics of materials is a basic professional course for engineering students starting in their sophomore year, and is also their first course highly involved in engineering practice [4][5]. It serves as an important link for the cultivation of students' abilities in engineering application and innovation capabilities.

In order to better cultivate mining engineering-related talents with engineering and innovation abilities, Jiangxi University of Science and Technology has attempted to reform the teaching of the *Mechanics of Materials* course in recent years. Taking advantage of the teaching reform, a research topic named *Teaching Reform and Practice of Basic Mechanics Courses in Mining-oriented Colleges* is being carried out by the Key Laboratory of Experimental Teaching Centre in Mechanics at Jiangxi University of Science and Technology and by the Education Department of Jiangxi Province, according to the three key teaching principles of Jiangxi University of Science and Technology (a solid foundation, diligence in work and honesty in life). Students' engineering application and innovation abilities are cultivated by theoretical teaching, experimental teaching, extracurricular scientific innovation activities and various competitions.

Each aspect of this complex approach has a different focus. Theoretical teaching places emphasis on the training of innovation and engineering consciousness, experimental teaching puts emphasis on the cultivation of practical abilities and engineering application, whereas extracurricular scientific innovation activities and various competitions put emphasis on integrating the training with development in engineering innovation. After several years of persistent effort, a new model with vivid characteristics for teaching mechanics of materials has been developed.

THEORETICAL TEACHING EMPHASIS ON THE TRAINING OF INNOVATION AND ENGINEERING CONSCIOUSNESS

In theoretical teaching of mechanics of materials courses, the focus is on the principles of *quality education, engineering education and innovative education* that would help develop research- and practice-oriented teaching, and establish rich teaching resources for research-oriented teaching of mechanics of materials, including a series of typical engineering cases, in-class test exercises, training in research-oriented topics and scientific literature reading. In the latter part of the course, students are required to select a research topic related to their profession, and commence activities, such as to search for and read the related literature, carry out studies of academic research in the field, write short papers on such studies, etc. About a hundred of such papers on research studies have been produced so far, and they are of high quality. The specific activities are described as follows:

Introduction of typical engineering cases to enhance students' engineering concepts: mechanics of materials is a topic present in almost every engineering related activity. It may seem for some that the concepts, theories, principles and formulae of mechanics are boring, but they are widely applicable in engineering [6][7]. Therefore, by incorporating specific engineering cases and engineering accidents in the teaching of such content, especially the analysis of mechanical principles in catastrophic events related to inadequate mechanical strength, stiffness and stability, would not only stimulate the learning interest of students, but more importantly shorten the distance between theory and practice in engineering, thereby, strengthening engineering concepts and consciousness in students.

Introduction of academic literature related to the teaching content to enhance students' research capabilities: generally, there is no academic literature concerning the teaching courseware on mechanics of materials. However, the collection, searching and reading of the related literature not only are important elements of scientific research, but they would also allow students to trace the formation and accumulation of knowledge, thus, cultivating students' abilities to acquire and apply knowledge, which is not readily achievable by simply reading books [8]. This is especially important for cultivating innovative consciousness, innovative abilities and research capabilities of students. For this purpose, the authors of this article encourage students to read the literature based on the teaching content of mechanics of materials, at a level slightly higher than the content in textbooks usually recommended; thereby, greatly widening the academic vision of students, strengthening their research consciousness and developing research capabilities.

Introduction of engineering research-oriented questions to enhance students' learning abilities: in current mechanics of materials courses, there are only standard answers to academic exercises and questions, which greatly limit the thinking process of students and would not help the cultivation of divergent thinking. Practical problems in engineering are usually very complicated. When faced with a practical problem, one should analyse and investigate the problem in order to come up with the formulation of the question, the construction of a model, the use of proper theories and methods to solve the problem, with necessary conditions and given data. Often practical problems do not have standard solutions or model answers. Hence, in the teaching of mechanics of materials, the incorporation of research-oriented questions can consciously cultivate and strengthen students' learning abilities in the context of problem-solving and future research.

EXPERIMENTAL TEACHING EMPHASIS ON THE CULTIVATION OF PRACTICAL ABILITIES AND ENGINEERING APPLICATIONS

Establishing a classification system of experimental teaching for transforming the educational thought process and strengthening the cultivation of student abilities: to tackle the unhealthy attitude of *cherishing theory more than practice, and cherishing knowledge more than abilities* widely seen in college and university students, the educational thought process must be transformed from the traditional transfer of knowledge to the cultivation of abilities. A classification system can be established for the experimental teaching of mechanics of materials, with the following four types of mechanics of materials experiments:

- Cognitive experiments: such experiments are interesting and intellectually involving;
- Basic experiments: for consolidating basic theories, since in the practice of teaching it has been realised that basic experiments form the basis in teaching theories. At the same time, when optimisation and refinement are required, verification can be reduced and exploration can be added, so as to improve the teaching;
- Integrated design experiments: for integrating engineering-cultivated practical abilities;
- Research innovation experiments: for fostering innovative spirit and capabilities.

Cognitive, basic and integrated design experiments can be conducted mainly in the classroom setting, whereas research innovation experiments can be conducted through extracurricular scientific activities and competitions, thereby, establishing a progressive teaching model of *fun, knowledge-towards-basic theories-towards-engineering practice-towards-academic advancements*. The objectives of the curriculum in experimental teaching are to guide students to transform the learning of knowledge to the enhancement of abilities, eventually achieving the development of self-motivated innovation.

Development of original experiments integrating mining engineering based on disciplinary advantage: a Centre for Mechanics Experiments has been in operation at Jiangxi University of Science and Technology for more than 50 years, with considerable achievements in developing basic experiments. It also has significant achievements in establishing a base in mechanics, setting up teaching reform and delivering excellent courses in mechanics. Based on this disciplinary advantage, with much attention on the transformation of scientific research and achievements to teaching resources, many original experiments in mining engineering have been developed with an emphasis on engineering practice. More than 800 person-times have participated in such experiments, laying a solid foundation for students to cultivate their engineering application and innovation capabilities. Typical examples of such independent experiments from the perspective of mining engineering include the development of experimental systems on concrete pillar mechanics, the development of experimental systems on bolt pulling mechanics, and others.

Establishment of the teaching model based primarily on independent practice by students, and secondarily on teacher guidance, an approach combining focused teaching and individualised instructions: in experimental teaching, focused teaching is adopted for the teaching of theories in basic experiments, while the practice of basic experiments is primarily based on students' independent practice. Teachers help students by emphasising the development of thinking and enlightenment. On the basis of completing teaching requirements, students with better foundation are encouraged to perform innovative engineering experiments and to write short papers, with those excellent papers awarded with bonus points in final examinations. There are students opting to perform such experiments each year. There are two types of such experiments: 1) original design experiments by students based on existing devices; and 2) design of brand new experiments by students, e.g. studies on the stability of locally weakened columns of slender concrete pillars in the mine.

EMPHASIS ON EXTRACURRICULAR SCIENTIFIC INNOVATION ACTIVITIES AND VARIOUS COMPETITIONS IN THE DEVELOPMENT OF ENGINEERING INNOVATION

Participating in teacher-originated research projects: students' participation in research supported by the Student Innovation Fund, and in scientific research groups of teachers, enable them to develop innovation abilities at a higher level. In recent years, under such effective teacher guidance, students in mechanics of materials courses have applied for nearly 10 projects under the College Students Innovative Training Program, including one at the provincial level.

A Jiangxi University of Science and Technology teaching team in basic mechanics consists of a number of outstanding teachers, with teaching outcomes well received by domestic peer experts and students. The teaching team is also an excellent scientific research team, responsible for various National Natural Science Foundation Projects, *863 Projects* and provincial natural science foundation projects. Strong academic support provides a good platform for the training of innovative talent. There are students in mechanics courses entering teachers' scientific research teams every year. These students receive training through participating in advanced scientific research, with some of their theses or graduate design projects originating from such participation.

Participation in a variety of competitions in mechanics: extracurricular scientific innovation activities and various competitions present an outstanding opportunity to inspire the interest of students with innovative potential, leading them to actively participate in these activities and to develop their comprehensive abilities. With the general improvement in teaching quality, a group of top students has emerged. They have performed admirably in national college students *Pei-yuan Chou* mechanics competitions in recent years, including winning national third-place prizes, and more than 10 students winning first- and second-place prizes in the Jiangxi division. Many students won second- and third-place prizes in the National Mathematical Modelling Contests through application of their knowledge on basic mechanics. Two teams of eight students also won prizes in the National Challenge Cup contest for college student entrepreneurs.

COMPARATIVE ANALYSIS OF TEACHING OUTCOMES

The following is a comparative analysis of teaching outcomes, showing the effects of teaching of the mechanics of materials course given under teaching reform on improving engineering application and innovation abilities of students. The results of various academic activities of 89 undergraduate students majoring in mining engineering from the Class of 2010, who studied the course under the teaching reform, and 82 undergraduate students in mining engineering from the Class of 2009, who did not experience teaching reform were compared. The analysis was conducted on four aspects: the excellence rate of graduation thesis; the proportion of publication of academic papers; the award winning rate in innovation and entrepreneurship competitions; and the employer evaluation of job performance by students. The results are shown in Table 1, and the subsequent Figures 1, 2, 3 and 4.

Table 1: Results of quality indices of students before and after the teaching reform in mechanics of material.

Project name / Class	Excellent graduation thesis			Publication of academic papers			Award winning in innovation and entrepreneurship competition			Employer evaluation of job performance by students		
	Count of excellence	Total number of students	Excellence rate	Count of publications	Total number of students	Publication rate	Count of awards	Total number of students	Award winning rate	Count of excellence	Number of respondents	Good reputation rate
Class of 2009	5	82	6.0%	8	82	9.8%	12	82	14.6%	4	15	26.7%
Class of 2010	9	89	10.1%	17	89	19.1%	20	89	22.5%	6	12	50%

Figure 1: Comparison of the excellence rate of graduation theses of students.

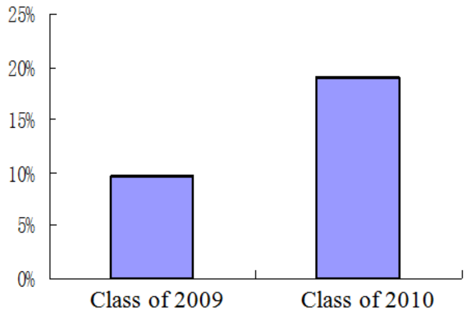

Figure 2: Comparison of the proportion of publication of academic papers by students.

Figure 3: Comparison of the award winning rate in innovation and entrepreneurship competitions of students.

Figure 4: Comparison of the employer evaluation of job performance by students.

As can be seen in Figure 1, only five graduation theses were excellent in the Class of 2009, before teaching reform in mechanics of materials, with an excellence rate of 6%. On the other hand, nine graduation theses were excellent in the Class of 2010, after teaching reform in mechanics of materials, with an excellence rate of 10.1%.

For the publication of academic papers, the publication rate for students in the Class of 2009 was 9.8%, but the publication rate for students in the Class of 2010 was 19.1% (see Figure 2), that was significantly better than before the teaching reform.

As shown in Figure 3, students in the Class of 2009 participated in the innovation and entrepreneurship competitions and won 12 awards before the teaching reform of mechanics of materials course, whereas students in the Class of 2010 won 20 awards in the innovation and entrepreneurship competitions after teaching reform. The award winning rate increased from 7.9% to 22.5% with the teaching reform.

More importantly, after graduation when students became employed, the authors of this article visited randomly selected employers of 15 students in the Class of 2009, and four of them enjoyed good reputation among the employers; whereas among 12 students in the Class of 2010, six of them enjoyed a good reputation among their employers. The good reputation rate significantly increased from 26.7% to 50% with teaching reform (see Figure 4), reflecting the significant improvements in their engineering application and innovation abilities; thereby, earning good reputation among employers.

CONCLUSION

With several years of exploration and practice, the experience of the mechanics teaching team at Jiangxi University of Science and Technology has been based on the disciplinary advantage, development of research-oriented teaching, inheritance of good traditions, and the transfer of achievements in experimental teaching and scientific research into teaching resources.

The engineering and innovation abilities of students can be cultivated gradually by the use of different means, including theoretical teaching, experimental teaching, as well as extracurricular scientific innovation activities and mechanics competitions. While the quality of teaching is generally improved, the emergence of talented people with self-motivated innovation abilities is an especially welcomed achievement as it has been encouraged through a variety of new methods and tools.

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