A model to strengthen mechanical engineering training

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ABSTRACT: The new century provides challenges to satisfy the need for higher mechanical engineering graduates. Outlined in this article are ideas for cultivating students' innovative and creative abilities. The reforms have the engineering quality of the students at its core. The curriculum and teaching were optimised by the application of modern educational technology. The new model cultivates students' innovative ability. By strengthening engineering training, the students can learn to carry out research, innovation and improve their practical ability. This promotes autonomous learning and the initiative and motivation to learn. The students learn to apply knowledge so as to solve engineering problems.

INTRODUCTION

With the new century, the global economy has been experiencing a transition from an industrial to a knowledge economy. The knowledge economy is a new, vital economy in the era of computer information. It brings knowledge of production and the human intellect into full play with informatisation and the network as the foundation. Innovation and the effective use of resources promote science and technology, the economy and society to realise sustainable development [1].

Engineering education in China is in need of reform of content, method and means. It needs to be competency-based, collaborative and open, so as to adapt to the requirement of engineering in the knowledge economy.

The knowledge economy is knowledge-based with high-tech industry as the pillar. Continuous innovation is at the core of the economy, and it depends on engineers to convert knowledge into the final products. China is facing new challenges after joining the WTO (World Trade Organisation). With the popularity of higher education, there is an urgent need to change China's education, from being examination-oriented to promoting creative and innovation ability. Higher engineering education is no exception. The knowledge economy requires mechanical engineering education to promote mechanical engineering and technical personnel with innovative ability. The cultivation of innovative talents, when fully analysed, requires changes to the training and curriculum in higher education.

MECHANICAL ENGINEERING TRAINING IN THE NEW CENTURY

Modern society has entered the information age of global information-sharing. The traditional machinery industry, combined with information technology has resulted in the rapid development of mechanical engineering [2]. Cultivation of high-level skills for a new generation of mechanical engineers is a primary task of mechanical engineering education. Mechanical engineering education should provide a solid theoretical foundation, broad knowledge, strong practical ability, computer application ability and a high standard of professional English with proficiency in English reading, listening, speaking and writing. The education should also pay more attention to overall quality and innovative ability.

In the past era of the planned economy, starting in the 1950s, the higher education system in China mainly followed the pattern of education in the former Soviet Union. The education was narrow and too specialised and did not produce the professionals needed to play a positive role in China's economy. China was left relatively backward, with its industry badly in need of professional talent. With the development of society, especially after the reform and *opening up* of the economy, leading to a market economy, and with the development of science and technology, the traditional *specialist* training mode is becoming more and more unsuitable and defective. The students' training was too narrow.

Reform of the traditional way of training is not to deny the past, but is rather a renewal aimed at fostering innovative ability. The rapid development of science and technology has greatly enriched mechanical engineering and other traditional disciplines, such as materials science, management and the humanities. The borders between disciplines have become increasingly blurred [3]. To adapt to the needs of the times, the general idea is to promote *good morals, solid foundations, strong ability, broad adaptive professional training.*

At present, there is a great emphasis on cultivating the morals of China's college students. Graduates should possess basic, social and occupational ethics. They should be enterprising, dedicated and collaborative.

Modern society inevitably requires mechanical engineers with a broader base of knowledge. Reform of teaching and curriculum is required, with particular stress on the practice of mechanical engineering. Enhanced ability is at the core of improving educational quality. This is a comprehensive ability, which includes the ability to self-educate (i.e. access knowledge from the Internet, be able to discard the false and retain the true, discard the dross and select the essential, learn from others' strengths); thinking (i.e. analysis and synthesis, logic); innovation (i.e. innovative thinking, research the unknown); information processing ability; and fluency with language (i.e. reading, writing, listening, oral expression).

Mechanical engineering students should have strong practical ability. They are required to adapt to society's actual needs for skills. The diversity of societal demands for skilled people drives the diversification of mechanical engineering education to meet the different needs of society. Following China's entry into the WTO, there is a need to focus on the challenges of globalisation, including cultivating students' awareness of the global economy and fostering talent that meets international standards.

Therefore, to adapt to the new era, there is a need to deepen the reform of mechanical engineering education and build 21st Century personnel training requirements for new, higher education mechanical engineering training programmes. These should foster a quality education using an open platform for innovative education.

TRAINING OF INNOVATIVE TALENT IN MECHANICAL ENGINEERING

Cultivate Students' Innovative Thinking

Creative thinking is a complex activity. It has two characteristics: first is the unity of logical and non-logical thinking (thinking, intuition, insight, inspiration); second is the unity of convergent and divergent thinking. Innovation does not come out of thin air but may result from research, a technological breakthrough, exploration of an existing mechanism, a redesign or by analogy [4]. Innovation often involves the derivative of an existing system to give it better operability.

One of the problems of modern education is that educators lecture on detailed and appropriate knowledge, which the students fail to think about inquiringly resulting in classroom *cramming* of knowledge, which will be forgotten in a very short time. Guiding students in active creative thinking enables them to grasp the essence of the material. If modern educators paid attention to this, students' learning would no longer be rigid and machinelike. They would be better able to understand a knowledge area and draw inferences about other things. To cultivate this new era, mechanical engineering education needs to be reorganised and the teaching content optimised. The traditional curriculum needs to be changed, with the establishment of *analysis and design* as a guiding principle.

To cultivate students' creative thinking ability, first of all, the educators should stimulate the students in the classroom. It is not realistic to simply give more and more information to students. Only through inspiring, engaging and prompting the students can develop their interest, enthusiasm and active, independent thinking be stimulated. It is only then they will be taught true knowledge and skills. Second, the content of each chapter of a textbook should not be seen in isolation. The teacher can, by comparing parts, make knowledge become an organic whole, which is easier to master. Third, students should be introduced to creative thinking to reduce thinking constraints and increase thinking freedom; hence, cultivating high-quality thinking. Fourth, education should be guided by the direction of development of modern machinery. Always pay attention to the new *hot* development, continuously enrich the teaching content and look for new ideas to stimulate students' interest in mechanical innovation.

Strengthen Core Engineering Quality

Scientists *understand the objective world* while engineers *want to change the objective world*, which is the objective of higher engineering education. China's industrial development and the situation in its higher education system lead to much structural adjustment, especially so, from the late 1950s, in the engineering technology institutes, which are now in danger of disappearing. But China's early 21st Century industrial reality requires engineering and technical personnel with specialised knowledge to meet its society's needs. Higher engineering education has accounted for more than 40% of higher education overall, and is the largest profession represented. Higher education mechanical engineering graduates must have acquired good skills, and the core of the programme should be an emphasis on the engineering quality of them.

Engineering quality is composed of knowledge, technology and skills; and it is important to measure the quality of higher engineering students [5]. Traditional education gives priority to imparting knowledge. Quality education imparts knowledge but also cultivates abilities that integrate and co-ordinate improvement in thinking. In the past, teaching was heavy on theory, but light on practice and ignored the application of theory. Instead, the theory should be established with practice by strengthening practical teaching and paying attention to engineering applications. In the past, teaching centred on the teacher. Teachers teach and students passively learnt. What is required is to establish students as the subjects of the teaching and to pay more attention to students' independent learning ability and creativity.

The teaching content must cover more of how theory is applied to mechanical designs, to enable students to better grasp how the knowledge can be applied in practice. Therefore, the teaching reform should emphasise innovation and practical training, and strive to cultivate and improve the design ability of students, to reach an understanding of modern mechanical design. To cultivate high-level mechanical engineering application-oriented skills, it is necessary to gradually build the core training scheme by combining engineering teaching with engineering practice. Add to this skills competitions and innovation, as well as creative product competitions, to cultivate students' innovative ability.

Training programmes form a series of dichotomies from simple to complex, from perceptual to rational, from foundation to comprehensive, from inside to outside, from junior to senior. It is multi-level and comprehensive. The content of the process of project teaching of undergraduate courses highlights the cultivation of innovation ability. The training programme is divided into four levels, as shown in Figure 1. Each level has a different content and different credit training programmes for students to choose from.

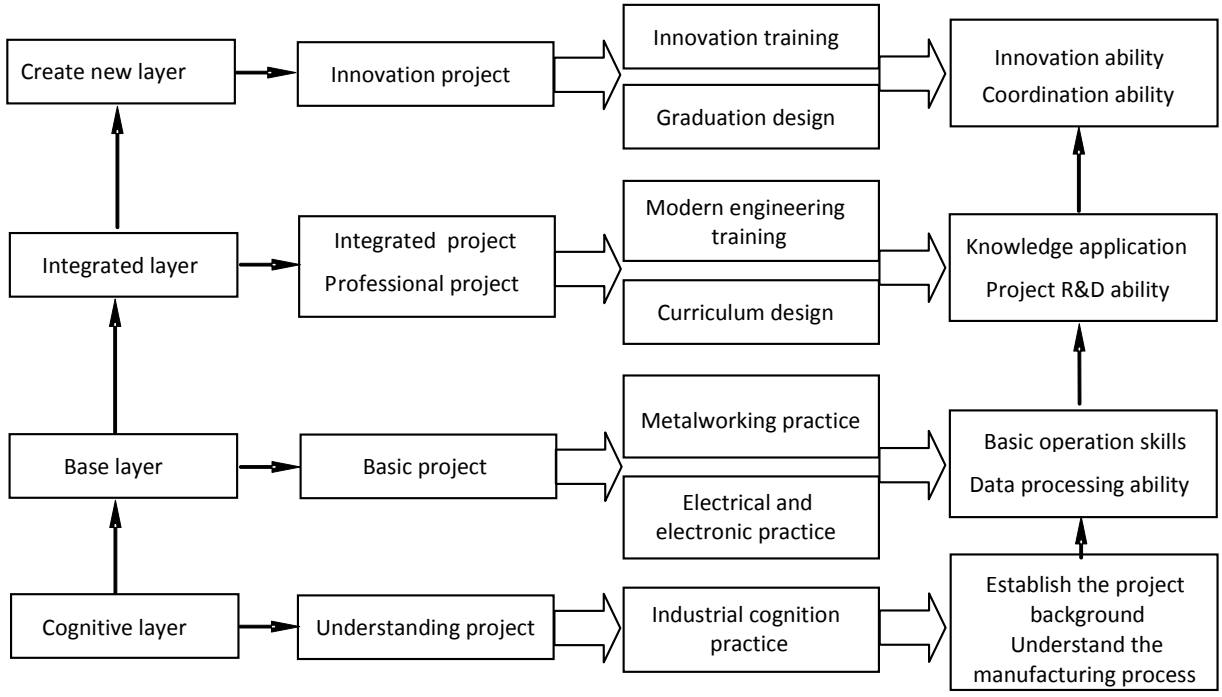

Figure 1: Structure of engineering training based on projects.

The cognitive layer training programme: the purpose is to train students in the manufacturing systems and processes of cognitive engineering. Through different professional presentations and some practical analysis of different professional designs with different sets of content, students lay an appropriate engineering foundation.

The base layer training programme: engineering skills are developed through a combination of concentrated and more dispersed training. The content and project depends upon the student's major. The students learn about engineering processes, improve engineering practice and receive preliminary training on innovative ability.

Integrated layer training project: according to different teaching plans and students' interests, the project gives priority to comprehensive thinking and innovative ability. It combines advanced engineering technology with comprehensive practical training apart from the projects. It improves the students' ability to analyse and solve problems and enhances their engineering ability. It further develops students' innovative abilities.

The innovation training project: emphasises practical teaching outside of the school. It involves the establishment of students' innovative project activity groups, uses scientific research projects and creates subject project competition. The project combines engineering design with practical teaching. It will improve students' capacity for innovation and operational practical processes. In addition to the engineering training centre-provided training programmes, students can get approval for their own projects according to personal interests and abilities.

The above multi-level project training deals with the whole process of undergraduate teaching. It is advantageous to the different specialties and to the different levels of the needs of the students. Flexible teaching methods are used to arrange the practical training, and to cultivate students' practical and innovative ability.

Reformed Course and Teaching Content

The training programme documentation details the organisation and pattern of teaching for a course. The course content includes the constructed teaching platform for the subjects. There is an increase in the proportion of electives and a strengthened combination of engineering teaching and practice. Mechanical engineering teaching content and course system reform is based on the idea *to NC (numerical control) machining as a leader, to CAD/CAM as the main line*. The aim of the reform is to broaden the base of modern science and technology, strengthen the practical content and, especially, information technology, which is an important part of mechanical engineering reform. The NC machining is high technology and includes information technology. It is the product of machinery and electronics, and involves many related fields and cross-disciplines. The constructed mechanical engineering curriculum has widened the subject foundations and promoted the reform of the specialty teaching content; thus, greatly enhancing the competitive advantage of the graduates.

Computer-aided technology is used in teaching and design, especially for CAD/CAM. The CAD/CAM includes product design, engineering analysis, processing and simulation. The whole design is displayed in 3D and is consistent with real life. This is helpful for students in developing their potential in design. The reformed course cultivates the calibre and adaptability of the machinery professional. The previous course was too specialised and the teaching content too narrow.

To broaden the basics, mathematics, physics, mechanical engineering, electrical engineering, electronics, computing and foreign languages should be strengthened. In the new curriculum, there is an increase in engineering practice to more than 40 weeks. Strengthening engineering practice cultivates students' practical ability, the ability to solve practical problems and inspires their thinking.

Continuous foreign language teaching should be ensured for four years. Project teaching and engineering practical teaching should be ensured for four continuous years. Comprehensive and innovative practical teaching should be designed so that it takes not less than 50% of the total time. Also, practical work should be strengthened to use the technology and equipment of advanced modern enterprises. Credits should be added into the training programme to encourage students, in their spare time, to participate in various skills competition, to follow up academic reports, etc. The skills competition consolidates classroom teaching and metalworking practice. Engineering uses technology based on scientific theories to change the objective world. It is a creative profession and, therefore, must take the cultivation of students' engineering and innovative abilities as the core [6]. In order to cultivate students' innovative spirit and creative ability, they actively participate in the mechanical innovation design competition.

The curriculum covering mechanical drawing, mechanical principles and mechanical design was based on the *design theme* of restructuring and optimisation. The mechanical drawing course focuses on the cultivation of students' spatial ability through an increase in 3D content and ability to express design ideas using computer graphics. The mechanical architecture in the mechanical principles course was changed to highlight system mechanisms. The mechanical design course was strengthened, with more emphasis on integrated design and overall grasp by the students of mechanical systems. Engineering materials, metal technology and measurement technology courses were strengthened to include new materials and special manufacturing processes, so as to lay a good foundation for a design.

Computer graphics and mechanical parts courses were reformed to implement CAD/CAM as the main line. These two classes, with the numerical control programming, CAM technology and other courses of study, enable students to complete their knowledge of CAD/CAM. The innovative design of the course mechanical systems aims to cultivate students' innovation ability through classroom teaching and product design, and also by an innovation design contest and other extracurricular activities.

Application of Modern Education Technology

The optimisation and reform of teaching and the curriculum of mechanical engineering courses has resulted in less and less teaching time. But with the development of science and technology and the progress of machine design, there is more and more content to teach. How to complete the teaching contents stipulated in the limited teaching hours and achieve better teaching is a major challenge. To address this, in addition to the teaching content, teachers should focus on key areas, clarifying principles, design methods and applications. Teachers should try to shorten the lectures and make full use of various modern teaching means to improve the teaching. In teaching, they should make full use of material objects and models to demonstrate in the classroom, which increases student's perceptual knowledge. Video allows students to see parts of the structure, the working principles and application of various kinds of machinery. This gives students a deep understanding of engineering and stimulates their interest in learning. Multimedia CAI (Computer Aided Instruction) teaching; especially, three-dimensional computer animations can make students better understand principles than in traditional classes. This makes classroom teaching more vivid and intuitive and saves the teacher's time writing on the blackboard.

In conclusion, the application of multiple effective teaching methods can change traditional teaching and make the classroom teaching more lively and vivid, increase the interest and enthusiasm of students, and also save a lot of teaching time. Teachers can, at the same time, convey more knowledge and information to students and, hence, the teaching improves. In teaching, it is necessary to recognise that various teaching methods have their own characteristics, and the teaching should give full play to the strengths of various teaching methods, which complement each other. Modern teaching methods and traditional teaching methods organically complement each other. Full play in teaching should be given to the initiative of students and twice the result should be obtained for half the effort. The system to cultivate the innovative abilities of higher mechanical engineering students is shown in Figure 2.

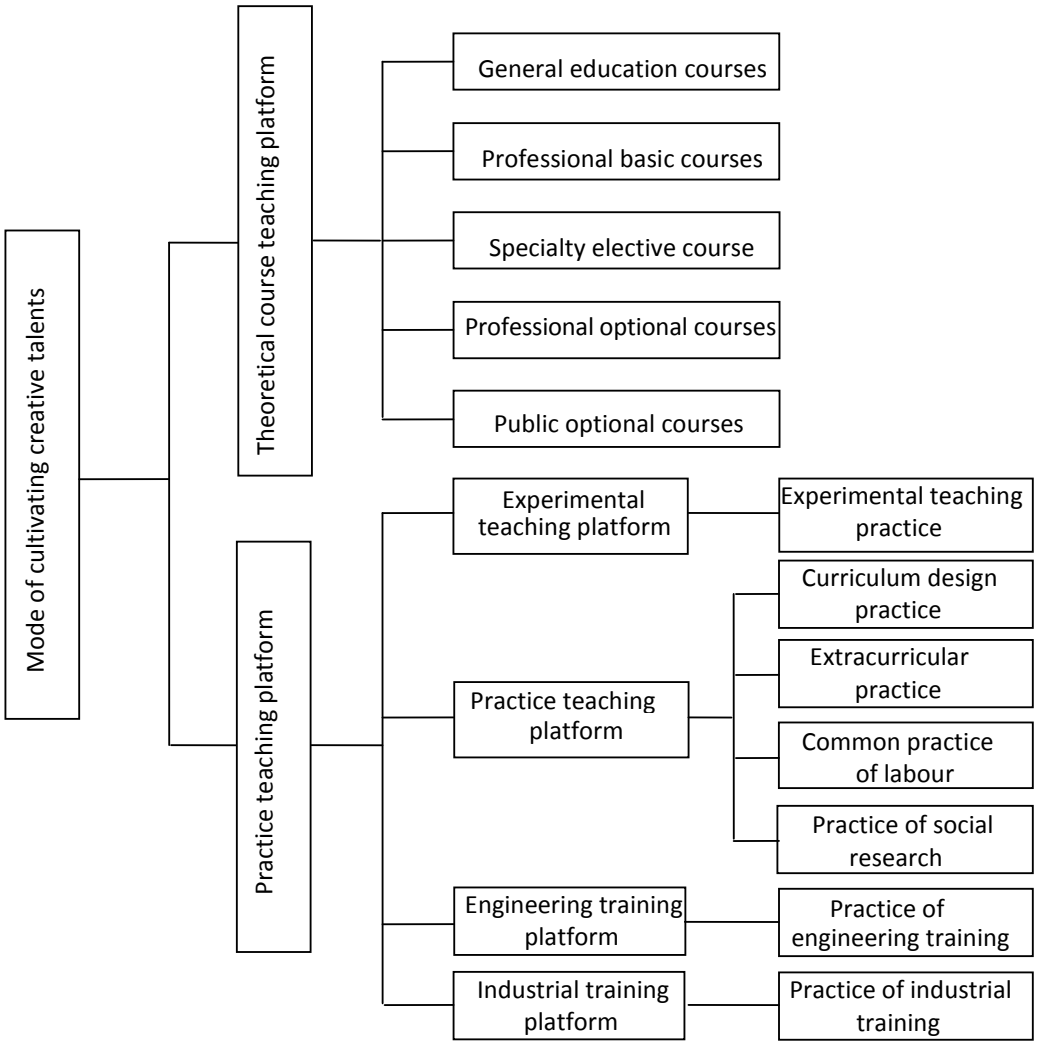

Figure 2: Cultivating creative talent.

CONCLUSIONS

The training of mechanical engineering students should recognise that although the training is controlled by teachers, students are the main subjects. Engineering training should focus on an organic open combination of mechanical and electrical engineering. Traditional metalworking has been transformed by the use of contemporary engineering training methods, including the use of projects. The aim is a comprehensive quality education in the classroom, enhanced practical ability and a cultivation of students' innovative ability.

The reform of higher mechanical engineering training in the new era must be comprehensive in order to achieve a good result. Indeed, the reform has been popular with the students. Students' learning and satisfaction with the teaching have been improved greatly. The reform also has greatly enhanced the teacher's knowledge of theory and their practical ability.

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