World Transactions on Engineering and Technology Education
Vol.11, No.4, 2013

Reforming the teaching of mechanical design for industrial design students

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ABSTRACT: There are several common problems in teaching mechanical design to industrial design students that lead to inefficiency, student discontent, and a lack of practical content in making effective use of theory. The authors have analysed these problems and, accordingly, have reformed the teaching programme for mechanical design. The main reform measures include focusing on practical application, adjusting the time allocated for the course contents and reducing the amount of mathematics. The reformed teaching programme aims to motivate students to acquire knowledge by studying motion mechanisms, combining perceptual and rational experience and enhancing professional confidence. Teaching practice shows that motivating students' interest should be the first priority for educational institutions. On this basis, strengthening the study and application of practical design cases could greatly improve industrial design students' mechanical design ability.

INTRODUCTION

Industrial design is a profession most closely related to the manufacturing industry. Industrial designers have the responsibility of developing products. They need a considerable understanding of mechanical mechanisms to ensure their products have a competitive advantage and to avoid infringing existing patents. Therefore, the Mechanical Design course has significance for industrial design students.

However, the teaching methods applying to the Mechanical Design course do not entirely satisfy the needs of the students who major in industrial design. An author of this article has been in charge of the annual *Chinese Hardware Products Industrial Design Competition* for five years. Reviewing the 1,500 pieces of work submitted to the competition each year reveals that the mechanical design ability of the industrial design students is quite limited. Participants in the competition are mainly university students studying industrial design and, usually, in the junior and sophomore years. Since the competition is held in autumn, participating students would have studied at the institution for more than two years and, by that time, completed the basics of the Mechanical Design course.

Among the products featured in the pieces submitted for the competition are hardware tools, scooters, home-use food processors and exercise machines. The discipline of mechanical design focuses on the best in design and innovation, but most works contributed to the competition were to do with style and appearance, while less than 10% of the works made use of advanced mechanical concepts (e.g. the four-link mechanism). This revealed the designers' lack of knowledge of mechanics. Thus, it is hard for them to add value to their design using advanced mechanical concepts. This is partially due to the teaching methods of the mechanical design course, and is a common problem nationwide.

The problem is not new. Many university teachers are aware of it, e.g. Liu L. et al analysed this issue in the teaching of mechanical design, from the aspects of interest, motivation, background knowledge, thinking and teaching [1]. In fact, they proposed a teaching principle of *major-applicable* (i.e. important topics), and *instance-emphasising* (of current significance). In response to the disconnection of the course content from the needs of industrial design students, Chen H. proposed *experience-based* teaching practice and innovative examination methods [2]. To stimulate interest, Shuai Y. adopted a variety of flexible multimedia teaching methods to improve teaching [3]. Based on the inherent differences between engineering courses and art courses, Zhuang Y. et al have proposed a mechanical design teaching philosophy of *seeking-common-points-while-reserving-differences*, so that engineering knowledge and artistic thinking can be integrated [4].

As regards the teaching content for industrial design practical sessions in mechanical design, Hu L. extracted key points and divided them into three categories viz. *validation*, *interdisciplinary* and *comprehensive*. His method made use of practical sessions to considerably positive effect [5].

Based on years of teaching experience, the authors found that industrial design students' *artist-mode thinking* is not the real reason that prevents them from learning mechanical concepts, though this assumption for years has been taken as correct. Combined with personal teaching experience, the authors made a number of suggestions on industrial design teaching methods for the Mechanical Design course, in the hope of promoting changes to the teaching of it, so that students are able to apply their mechanical design knowledge immediately, rather than start to learn the basic rules only after leaving school.

ISSUES IN TEACHING MECHANICAL DESIGN

The mechanical design course for the industrial design major at the authors' university was taught by teachers from the Mechanical Engineering Institute. Taking into account convergence with other industrial design majors, an industrial design teacher with a professional background in mechanics took over the course in recent years. The main problems encountered were as follows.

Lack of a Professional Environment for Learning

There are a small number of mechanical design components within the teaching programmes of the industrial design major, and these, usually, are independent of other course components. In contrast, the components of the mechanical design major interact and reinforce each other. This implies that the content of the mechanical design component within the industrial design course lacks the necessary cohesion to improve comprehension.

Engineering-style Teaching Content and Methods

The mechanical design course teaching programme and teaching methods tend to be in an engineering style; in particular, *wordy*, and with a high degree of abstraction. The teaching of mechanical principles generally is from the abstract to the concrete. Many principles of mechanics are limited to practical situations and, so it is hard for students to get a good grasp of them. One of the authors improved the teaching through the use of three-dimensional virtual animation, but the effect was not fully satisfactory, because the students still had inadequate mechanical knowledge. In addition, the usual teaching content for mechanical design tends to relate to manufacturing processes, structures and materials, while knowledge of the *movement mechanisms*, which designers care more for, is sparse.

Low Ability in Mathematics

Industrial design students generally try to avoid mathematics, even if it is only at high school level. One of the authors found that what the students lack is not mathematical ability, but the awareness of how to use it. Thus, it is necessary to promote students' application of mathematics through some complete design examples, which require real models to be made.

Weak Rules and Strong Innovation

The contents of the mechanical design course do not include basic principles, but rather they focus on the application of combinations of these principles, i.e. there is a feature called *modularisation*, which means students are required to have a general understanding of combinations of modules, as well as be familiar with how modules are interconnected. For example, students are supposed to learn how to choose the parameters of motors without having to know the theories about motors. The teaching of mechanical design still lays particular stress on the central knowledge required rather than on its application, and does not emphasise the linkages between modules.

Engineering students' application of their knowledge is described as being *strong-rule and weak-innovation*, that is, innovation is within the framework of given rules. Industrial design students are described as *weak-rule and strong-innovation* meaning that they may conceive new applications with feasibility as a secondary consideration. Different objectives require different teaching methods. A teaching style for *strong-innovation* needs to focus on the module combinations rather than one module having all the content. Having all knowledge contained in one module promotes a type of *strong-rule* working, while combinations of module promote a type of *strong-innovation* working.

PROGRAMME OF REFORM FOR MECHANICAL DESIGN

In response to the issues raised regarding the teaching content and methods, a series of measures were adopted to improve the teaching of mechanical design both in content and method.

Amended Course Aims and Focus on Applied Knowledge

The aims of the reformed course were to improve the industrial design students' understanding of mechanics, so as to enable them to apply mechanical principles to product design. The objective of the mechanical design course for the industrial design major has been converted from the original requirement to acquire knowledge to the application of knowledge; thus, putting to practical use the knowledge learned. The focus on a fixed textbook is no longer stressed, instead the teaching programme specifies a series of reference materials for students' self-study.

Reduce Mathematical Content

Most of the mathematics in mechanical design courses is at the level of middle school. Even so, the industrial design students' mathematical ability actually has been degrading continuously. Although this is unreasonable, any improvement would need to be done through collaborative efforts across entire courses. However, attempts can, at least, be made to make the mechanical course less affected by this situation. With limited class hours (48), a large amount of mathematical content was removed, except for two sections related to planar linkage degrees of freedom and transmission system speed ratios.

Convert from the Abstract to the Concrete: Acquiring Knowledge through Initiative

The teaching of mechanical theory was improved by combining theory with real-world practical experience. For example, mechanics theory taught through traditional methods (known as *chalk-and-talk*) was abstract (such as teaching about a mechanism from the concept of degrees of freedom), while the reformed methods start from one specific piece of knowledge, so that students can abstract general principles from mechanisms around them in their environment (such as umbrellas, scooters, bottle openers, juicers, bicycles).

In this way, they build mechanical knowledge through their initiative in studying everyday objects rather than being propelled passively along through theoretical concepts. The students are guided toward drawing conclusions on theoretical knowledge through practice and, by this process, their initiative and skill in applying knowledge is strengthened.

The new teaching methods have changed the original course content and teaching sequence by selecting practical-oriented knowledge directly related to product design. Among the existing teaching resources retained were the physical mechanical and the animated models. The teaching materials were arranged according to the needs of the industrial design major, in which the application of mechanical knowledge and problem analysis were stressed, with additional video presentations of typical mechanical products.

Highlight Motion Mechanisms and Exercises

Mechanical applications in industrial design mainly are concentrated on the motion mechanisms. Therefore, the course centres on planar mechanisms and transmission systems. This is designed to motivate the learning of the cam mechanism, the intermittent motion mechanism, flexible transmission and other types of mechanism. Training is also carried out on combined applications of a range of mechanisms in integrated design cases.

A large proportion of the content of modules was arranged around the two major points of knowledge taught. For example, the functions of the planar mechanism are divided into: copy, changing direction, scaling and other basic operations. Combined applications in problem-solving are carried out to give students experience in analysing situations while, at the same time, seeking solutions to problems through theoretical principles.

Combine Real and Virtual Models: Perceptual and Rational Modelling

The teaching is focused on strengthening two reciprocal procedures; these are *perceptual* practice and implementation verification. Perceptual practice is where the design is summarised through the use of abstract expressions (such as a schematic diagram or transmission system diagram). Implementation verification is where physical models are produced so as to validate the design. Students can grasp abstract principles by building such models. As well, it increases students' interest and sense of accomplishment in working with machinery.

Before making a physical model, students must design an interactive virtual animation with the help of parameterised software, such as SolidWorks or ProE. They, then, test and improve the design by modifying the physical features and mechanical functions of the virtual models by adjusting the parameters. Based on existing assignments, the modelling and testing were increased in examinations, so that students could develop a full understanding of their own designs, both theoretically and perceptually.

Case Study Teaching for Strengthening Practical Skills

The reformed teaching programme uses a case-based method as the basic principle, which includes two reciprocal cases: referred to as *perceptual-rational* and *rational-perceptual*. The perceptual-rational process is one of summarising a mechanism by producing a kinetic sketch of the mechanism. The rational-perceptual involves conducting further design improvements; thus, implementing students' own design ideas based on mechanical theory.

The cases to be studied are classed at several levels, gradually advancing from *easy* to *difficult*. Simple cases include an umbrella, speed-variable bicycle, more complex cases include clocks, computing mechanisms and special vehicles. The process cycle in case teaching is shown in Figure 1.

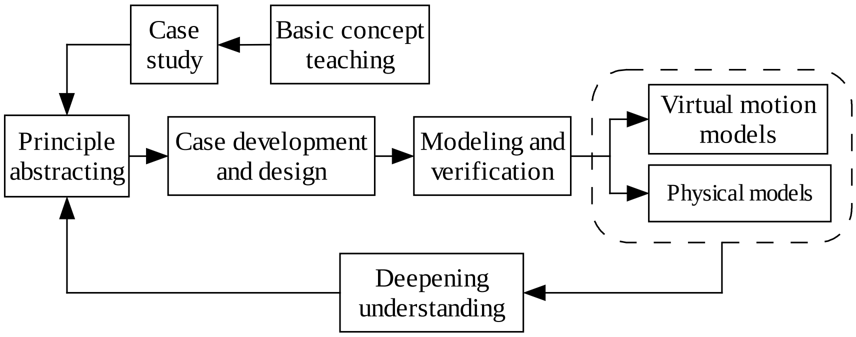

Figure 1: Teaching by case study.

Enhance the Sense of Accomplishment by Making Physical Models

The ultimate goal for industrial design students, who study courses on mechanical design, is to increase their advantage in product design and to eliminate the biased common impression that *industrial design is just styling*. In this regard, the authors' laboratory was equipped with 3D printers, an engraving machine and other equipment for model-making; thus, allowing students to turn their designs into physical models, which greatly enhances their sense of accomplishment and interest in *doing homework*.

Enhance Confidence by Upgrading Techniques

Industrial design students often need to make original functional prototypes, including some electro-mechanical or even intelligent products. In response to such a demand, the course teaching content was supplemented with an Arduino intelligent development platform. This part of the content is easy to learn and can be grasped by university students in a short time. Since this technology is relatively new, it has not yet been included in most mechanical or electronic professional courses. In being able to understand Arduino, students will develop better comprehension of creating functional prototypes of intelligent product than do students in courses on electrical or mechanical engineering, hence, giving them a professional advantage.

EXPERIENCE RESULTING FROM THE REFORM OF MECHANICAL DESIGN

The following experiences were gathered during two terms of teaching practical sessions to industrial design undergraduate students.

Interest Matters

It was found that interest is the main motivator in stimulating students' passion for learning and research. Figure 2 is a Red Dot Award scissor product demonstrated in explaining the planar linkage mechanism. The students were engaged in a wide-ranging discussion about its mechanical characteristics and usage, and also conducted a lot of computer research. Through debating the product and the requirements of the experiment - the *instance* - students gained a deeper understanding of the design and the properties of a four-link mechanism.

Figure 2: Red Dot Award scissor product.

Promoting and Developing Student Interest

It was found that design (and art) students' interest in learning is quite strong. Figure 3 shows a design produced by a student of an anti-gravity toy car. In addition to producing the mechanical parts, the intelligent hardware and software programs were all completed by the student herself. Figure 4 is an example of another creative electronic product containing mechanical parts, which also was made independently by the student himself. These cases are examples of how the so-called *difference* between the modes of thinking and the disciplines of engineering and art/design students are in fact not the main obstacle to learning mechanics. These difficulties can be overcome through good design themes and student interest.

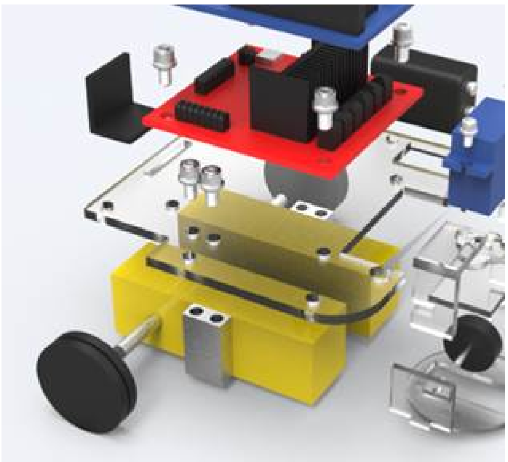

Figure 3: Student's anti-gravity toy car design.

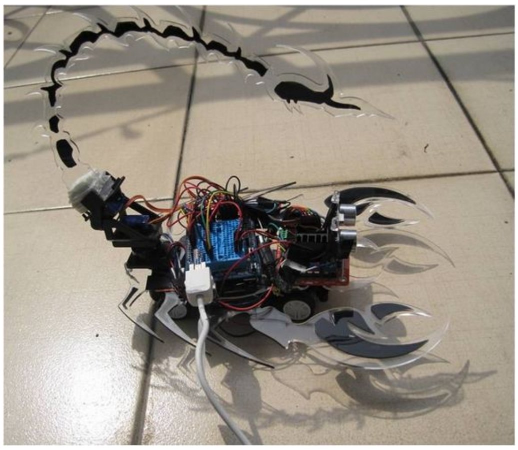

Figure 4: Student's electronic product design.

De-emphasising the Use of Textbooks

No textbook was specified for the course. Instead, a list of reference books was issued, including a mechanical design manual; a *mechanism atlas* (i.e. list of mechanisms) and other practical references. A clear statement also was made that the teaching material presented in class would relate closely to the examination. Students' concentration in class was greatly improved and, with the increase in students' attention and their absorption of knowledge, their interest in learning improved. The mechanism atlas was found to be more popular than were the explanatory materials that explained or described it; this indicates that students have a higher degree of acceptance of, and show more initiative in using, application-oriented knowledge than they do of pure theory.

Teaching from the Perceptual to the Rational

Huge differences exist between rational experience and perceptual experience, and rather than deal with purely abstract principles, the most important thing that attracted students' interest were the actual case studies. Students were greatly surprised on finding that the principle of a southward pointing cart (an ancient Chinese invention) and a double bicycle are identical. This greatly improved concentration in class. Since no-one in the class could describe from memory how a simple folding umbrella works, students' habit of observing mechanical objects in daily life needs to be improved. Then, they learn to understand and classify mechanical objects from a theoretical point of view. Also, the teaching of computing mechanisms, the ellipsograph, drawing mechanisms and trigonometric function-solving, as well as the design of other, more complex mechanisms triggered interest in mathematics.

CONCLUSIONS

The teaching of practical sessions shows that the first thing to do is to motivate students' interest. An emphasis on case studies in practical design greatly improves industrial design students' abilities in applying mechanical design theory. However, a teaching method such as this also presents a challenge to the teachers themselves. They will need to upgrade their techniques, such as is presented above with the Arduino intelligent platform. Although the skills related to the intelligent hardware are not high-tech, few industrial design teachers are familiar with it. Therefore, there is a need for the teachers to do their own learning before they can benefit their students' design skills.

ACKNOWLEDGEMENTS

This article is sponsored by the Teaching Reform Program *Industrial Design Major Oriented Teaching Method Reform on Mechanical Design Course* of Zhejiang University of Technology. The authors wish to express their thanks to ZJUT's generosity to support this work.

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