Development of The Undergraduate Mechanical Design and Practice Curriculum

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Abstract *— In order to bridge the gap between mechanical engineering education and industrial demands, a "Mechanical Design and Practice" course has been offered for the undergraduate majoring in mechanical engineering since the academic year of 1995. The aim is to cultivate students' capability of creative design and experience in prototyping. This course currently is reorganized into a series of "Mechanical Design and Prototyping Projects" courses. Each project was designed in such a way that junior/senior students have to apply previously learned knowledge, skill, and experience to engineering problems. These reorganized projects emphasize on hands-on practice on mechanical design and prototyping, in addition to theoretical analysis. This paper describes the current design of this course and the improvements, modifications and replanning of this course during the past seven years. Comments, reactions, and future planning, based on the seven-year running of the course and queries from junior and senior students, are also reported.*

Index Terms *— mechanical engineering, mechanical design and practice, mechanical design and prototyping projects*

INTRODUCTION

Engineering college graduates are the main resource of middle- and upper-level work force for industry in Taiwan. As technologies for product design and manufacturing change and improve so fast, product life cycle is thus dramatically reduced. Therefore engineering college students are expected to be sharpened with product design and manufacturing knowledge at school, in addition to theoretical analysis capability. This is an important issue in particular when industry faces the increasing competition in the global marketplace nowadays. For this reason, we need to modify, improve, or replan programs offered at school that could lead students to become productive engineers in their future.

In the past, the engineering college education over-emphasized on theoretical training while paid little attention to the cultivation of students' creativity and practical experience. It has been reported that students major in mechanical engineering (ME) were trained to become 'mechanical scientists' rather than to be 'mechanical engineers' in the past decades [1]-[2]. The side effect of such kind of training includes that college graduates are unable to apply their knowledge learned and experience accumulated at schools to the demands of industry; it is difficult for industry to grow and upgrade under competition in the world marketplace; and eventually students lose their interest in mechanical design and manufacturing which is the goal of mechanical engineering education.

In our opinion_a mechanical engineer should have the knowledge about how to translate engineering problems and demands into functional design, followed by mechanism and geometrical design; how to perform mechanical property analysis, part selection and fabrication, assembly and prototyping, testing, adjusting and fine-turning, refining, and trouble shooting during the design and manufacturing process; and finally how to integrate and to testify the entire process. In this paper, a curriculum established based on this concept for last seven years is discussed. The "Mechanical Design Practice" (MDP) course offered in the past is reorganized into a series of "Mechanical Design and Prototyping Projects" (MDPP) since the academic year of 1995[3]-[4]. These modified courses emphasize on hands-on practical training of mechanical design and prototyping processes in addition to original theoretical analysis training. These on-job training processes are expected to stimulate students' creativity and cumulate related knowledge in the learned process. It is also one of the goals of the MDPP courses that experience interchange through industry-supported projects will be able to provide students with more practical experience besides theoretical training in the college. Students are also expected to learn the methodology and attitude of teamwork through these processes.

DESIGN OF CURRICULUM

Although it is still arguing what should be taught to improve students' capability on mechanical design and manufacturing, educators and industrial representatives agreed that engineering college courses with more stress on practical training must be emphasized [5]-[6]. This agreement has been widely accepted in engineering colleges. For example, the Accreditation Board of Engineering and Technology (ABET) of USA has suggested that engineering departments at college should reorganize their teaching programs such that students can be better trained with industrial experience [7]. For mechanical engineering, courses that integrate design, analysis, and manufacturing can help students to overcome the transition from college to industry and should be included in the reorganized teaching program. Such courses will be beneficial for both college students and industry.

It is also reported that the discrepancy between current mechanical engineering education and industrial demands includes inconsistency, irrelevancy, insufficiency, and incorrectness [8]. It is therefore required to take this gap into consideration in designing the new curriculum. In our opinion, the new curriculum should equip students with the following capabilities:

1. understanding the process and related methodologies in mechanical design,
2. knowing about tools for design, analysis, prototyping, and their applications,
3. conducting system analysis and integration,
4. prototyping as a proof of design concept,
5. understanding the gap between design, analysis and manufacturing to accumulate the experience of DFM (Design for Manufacturability),
6. learning about the attitude and methodology of teamwork, and
7. learning about basic skill for project management such as resource planning, teamwork and schedule control.

The ultimate goal of a product design is to make it real though it may not be in a mass-production fashion. Therefore, a product design process can be viewed as the process that the designer is trying to describe his dream, subject to certain constraints, in order to make it come true [9]. This in turn needs certain analysis and manufacturing techniques. As a result, the college ME courses can be generally classified into three groups: (i) fundamental theory, (ii) basic practice and experiment, (iii) design, manufacturing, and design practice. They are organized in such a relationship that groups (i) and (ii) are the foundation of group (iii), as shown in Figure 1 [3]-[4], though some courses in group (iii) can be taught parallel with the other two groups. The concept behind the structure is to train students to employ the knowledge learned and experience accumulated from the courses in the three groups to the Mechanical Design Practice (MDP) course. Originally, the MDP course offers students geometry design and kinematics analysis as an extension of the Mechanical Engineering Drawing course with no practical hands-on prototyping. Although students can “imagine” the required manufacturing process in design process, they have little chance to see their designs turn into real in the class. Consequently they are unable to explore the gap between their designs and the processes involved to make them into a real product, not to mention accumulating DFM-related experience.

The problem, however, is not due to the course structure but to the teaching approach and course contents. In recent years, the MDP course has been adapted to fulfill the requirements at the department. However in order to strengthen students‘ capability in this area and to give them hands-on experience to accumulated DFM-related experience, the MDP course offered in the past is reorganized into a series of project-oriented Mechanical Design and Prototyping Project (MDPP) courses without changing the course structure [3]-[4]. These modified two-semester courses emphasize on hands-on practical training of mechanical design and manufacturing processes in addition to theoretical analysis. Students have to take at least one of the MDPP courses as a requirement for graduation. Students’ in the class are asked to complete a system or sub-system, not components, designed by themselves. In order to make their “dreams” come true students are forced to make these “dreams” more realistic while reserving romantic. They learned the “design-manufacturing cycle” through the iterative processes in furnishing their designs with feedback from analysis and manufacturing considerations. These on-job training processes are expected to stimulate students' creativity and cumulate related knowledge in the learning process.

Figure 2 shows the overall course structure of the arrangement based on the characteristic of each course [3]-[4]. The Basic Required Courses are the fundamental training for a college ME student. At this department, it is further divided into four tracks: design, analysis, mechatronics, and manufacturing. Courses in the design track stress on geometry, kinematics, related knowledge and tools. Courses in the analysis track provide students better knowledge and analysis techniques and tools for mechanics and dynamics. The mechatronics track, however, emphasizes on systematic analysis and integration, with concentration on electric-mechanical power, sensing, signal processing, and control. The manufacturing track furnishes students with related knowledge in manufacturing processes and material. Notice that each track also includes practice or experiment courses and thus the group of Basic Required Courses is equivalent to groups (i) and (ii) and certain part of group (iii) mentioned above. Students are then required to take Advanced Design Courses before or simultaneously taking the MDPP course. At this moment only the “Principles of Mechanical Design” course is required at the department while the other two courses are optional.

To equip students with better knowledge and experience for the MDPP courses, the department also provides supporting courses on advanced manufacturing, analysis, and mechatronics. Students are encouraged to take these courses to enhance their capability in certain area, depending on their interests.

IMPLEMENTATION

Although contents of MDPP courses are different according to the selected project, the common methodologies and approaches that leading students to complete the course are the same. These include reference searching, design process, system analysis, proposal writing, usage of handbook, functional arrangements, model design, product development, catalogue collection and part selection, practical mechanical design, practical engineering analysis, design management, local environment for machining, cost estimate, schedule control, sensor and controller, mechatronic system_tooling and machining, quality control, function testing and refining, and report writing. These topics are scheduled to give students better idea of practical design and manufacturing based on a regular academic year. These topics are taught by teachers at this department and invited industrial engineers and/or managers. Based on these common topics, it is believed that students have the chance to touch more industrial affairs. Besides, the relationship between academy and industry is strengthened. Therefore, the three-hours MDPP class is divided into an one hour common class and a two hours individual project class. The common class is for teaching those common methodologies and approaches topics, all students, no matter what project they selected, are get together to attend this class. The individual project class is for each project team to report and discuss with the teacher who instructs their project.

The MDPP courses are offered for the junior students. Students must enroll and complete one of the MDPP courses for graduation. Students are asked to form several teams with each team containing students with different specialty. Such arrangement is intended to enforce students to learn the attitude and methodology of teamwork, including but not limited to brainstorming, teaming-up, and integration, through these processes. It is also one of the goals of this arrangement that experience interchange through industry-supported projects will provide students industry-style working attitude and better practical experience besides theoretical training in the college.

For the purposes of evaluating the outcome, exploring the discrepancy, and promoting students' interest, an exhibition of students' projects is held at the end of the academic year with a contest for the best-achievement award. Teachers and industrial representatives are invited as judges for the contest. All students in the department are asked to attend this exhibition and to elect a most-popular award. Also an anonymous questionnaire is provided to each student who is currently attending this course in order to get feedback from students.

DEVELOPMENT AND MODIFICATION

This curriculum has made several modifications in the past seven years based the performance and feedback of students, and comments and suggestions from teachers. First, teachers for common topics now are all from our department without invited industrial engineers and/or managers. The reason is those invited industrial engineers and/or managers although have much practical experience but not everyone is good at relating the industrial experience with the basic theories and also most of them use complex systems as examples. Students know a lot practical methods used in the industry from the class but they cannot figure out how to apply theories learned before to their design. Therefore we rearrange the common topics and select suitable faculties of our department to teach these topics. A final written examination for these common topics is added to the class for evaluating the effect. Second, the two-semester MDPP courses were originally offered in the junior year, now is shifted to the second semester of the junior year and first semester of senior year. Because some of the advanced courses and supporting courses are offered in the junior year, students taking the MDPP courses without or simultaneously taking those advanced courses and supporting courses feel insufficiency or difficulty in theories application. Also this new arrangement let students have more time to work on their projects. Since there is an about two and half months summer vocation between this two semesters. Third, the evaluation method also made some change due to the increasing number of projects and for simplifying the grading process. The exhibition is held at the end of the first semester of senior year. Teachers, industrial representatives, and all students, from freshman to senior, are jointing together to elect three best-achievement awards. The evaluating grade has different weighting for teachers and students. The evaluation criterions are the originality, difficulty, interest, practicality, and display of the project. The grading sheets have different colors for students who already attended these courses and who have not. In this way, we can study students' point of view for those project results before and after attending these courses. Those comments and suggestions of invited people from related industry have been used as an input for the following course planning. Also each project team has to do the midterm and final presentation each semester to report their project progress to all teachers in addition to the weekly progress report to individual project instructor. Teachers then can give comments and suggestions, which may be different from their project's instructor. This also has the brainstorming effect but coming from teachers.

There were eight teachers instructed eight project teams for the first time offering the MDPP courses. There are about ninety students in this class and each team was form by ten to twelve students. In this structure, the team management is not an easy job especially for junior students. Project teams were formed in the beginning of class. Many students were not really interesting in this class in the beginning, but since they needed to fulfill the department's requirement so they attended this class. After one year working on their own project, their attitude was changed because they saw their design becoming a real thing. They knew how to apply theories learned before, which are no longer just some equations printed in the textbooks. They realized the importance of those theories. Actually they have more feeling about those theories than they first time studying them.

After executing the MDPP courses for seven years, now students show highly interesting in this class. They form the project teams long before the class beginning. Most teams are organized after they attended the exhibition of previous class. According to the feedback from students, some project's topics now are defined by student themselves then discuss with teachers to see the feasibility in this class. In this way, they feel that they can design and prototype something they are really interesting. Also there are thirteen teachers leading twenty-two project teams in the current semester. The number of students still is around ninety but each team is form by three to four students. This size of team has the best efficiency for this courses based on our seven-year experience. The team management is much more easy than before. Figure 3 to figure 8 are some prototypes accomplished in the MDPP courses for the past seven years.

The contents of common topics is shown in Table 1, which is arranged following the sequence from concept design, prototyping to product testing and modification. The topics of current projects for the MDPP courses are listed below.

1. Design and prototyping of fuel-economic vehicle
2. Design and prototyping of Chinese martial art training equipment
3. Design and prototyping of Stirling engine (I)
4. Design and prototyping of Stirling engine (II)
5. Design and prototyping of rock-climbing training equipment
6. Design and prototyping of wireless autonomous guided vehicle
7. Design and prototyping of Chemical-Mechanical Polisher
8. Design and prototyping of power wheel chair
9. Design and prototyping of hybrid powered vehicle
10. Design and prototyping of vertical take-off/landing flying device
11. Design and prototyping of creative bicycle
12. Design and prototyping mechanism of butterfly's wing
13. Design and prototyping mechanism of dragonfly's wing
14. Design and prototyping mechanism of bee's wing
15. Design and prototyping of computerized puppet
16. Design and prototyping of optical measurement device
17. Design and prototyping of die for metal forming (I)
18. Design and prototyping of die for metal forming (II)
19. Design and prototyping of transmission mechanism
20. Design and prototyping of tug-of-war training equipment
21. Design and prototyping of hovercraft
22. Design and prototyping of stair-climbing mechanism

As mentioned before, all the courses use the same design methodology and approaches. We believe this has enhanced students' capability in management as well as in techniques to address engineering design problems. Such capabilities are often not available in regular classes despite they are supposed to be part of engineering college training. Furthermore, as processes of different mechanical system design and prototyping are similar, outlines of these courses can be found similar though their contents are specifically designed for certain topics. Certain common methods, such as drawing techniques and the use of handbooks and catalogues, are the same for them and therefore can be taught at the same class. Such arrangement not only reduces instructors' efforts in preparing course material but also gives instructors more chances to explore different areas of interest because instructors are scheduled to teach common topics in turn.

Study on a seven-year trail of the MDPP course, based on queries from junior and senior students, showed that course projects are realistic, difficult, but interesting. It also indicated that students are satisfied with this programs, though course schedule and pressure are relatively tight and high. We also noticed that experience interchange via industry-supported projects equipped students with better practical experience besides theoretical training at school. Students also learned the methodology and attitude of teamwork throughout the design-prototyping processes. The other thing needs to point out is that the topics of projects become more variety, and more teachers in this department have interesting to lead the projects. Actually several more teachers want to joint this class but they must wait for next season due to the rule of school.

CONCLUSION AND DISCUSSION

Engineering education plays an important role in the society and therefore must be carefully designed to ensure that students are learning what required in the society. This article describes a series of project-oriented courses intended to give students major in ME more hands-on experience in DFM and more exploration to related knowledge in addition to theoretical training.

As the department locates in Central Taiwan, the heart of mechanical industry in this nation, we strongly feel the responsibility to furnish mechanical industry with graduated students close to what they need. We also want to point out that we are unable to make the course reorganization without the right timing and environment. These include several projects supported by the Ministry of Education, industry-supported co-ops and research projects, co-operation with nearby research and development institutes, and assistance from the Center for Mechanical Design and Manufacturing at the National Chung-Hsing University funded by the National Science Council. In the future, we will try to relate the topics of projects to industrial need as close as possible. We believe this can enhance the feature of the course and keep them on the right track.

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FIGURES AND TABLES

FIGURE. 1
THE RELATIONSHIP BETWEEN GROUPS OF ME COURSES.

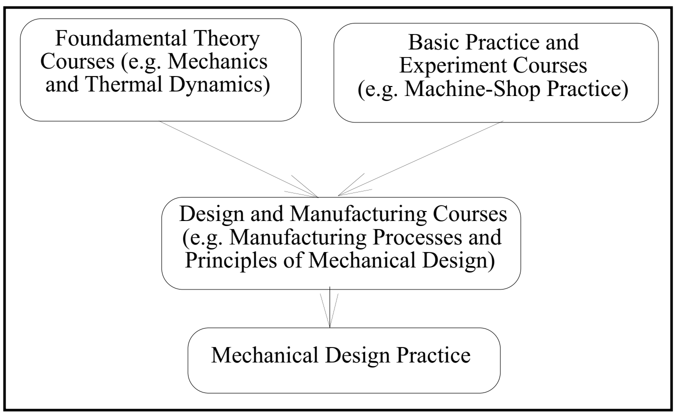

FIGURE. 2
OVERALL COURSE STRUCTURE.

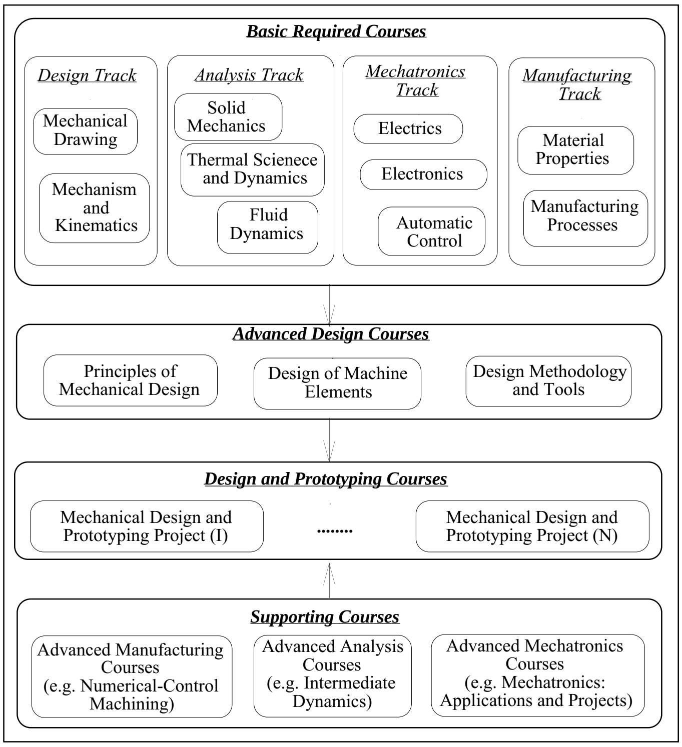

FIGURE. 3
ROCK-CLIMBING TRAINING EQUIPMENT.

FIGURE. 4
AUTOMATIC PAGE-TURNING MECHANISM.

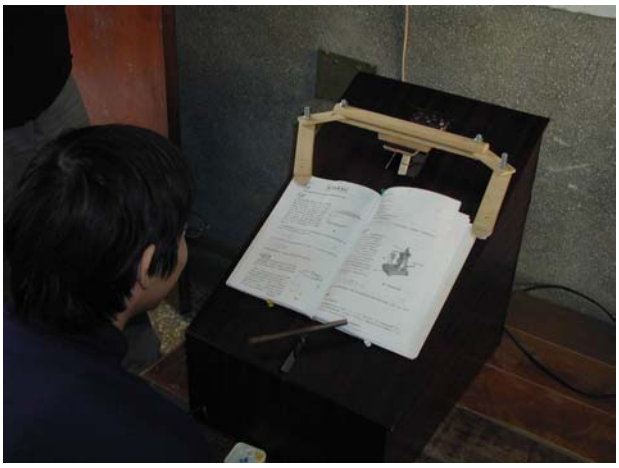

FIGURE. 5
HYBRID (ELECTRICITY AND GASOLINE) POWERED VEHICLE.

FIGURE. 6
THREE-AXIS PLATFORM.

FIGURE. 7
FOLDABLE POWER WHEEL CHAIR.

FIGURE. 8
SOLAR-ENERGY POWERED VEHICLE.

TABLE. 1
CONTENTS OF COMMON TOPICS.

Week	Topic
1	a. Courses introduction b. How to write report c. How to do the presentation
2	Machine shop safety rule and management
3	Function analysis and creative design
4	Drawing technique and standard
5	How to use handbooks and catalogs
6	Sensoring and control techniques
7	Power system selection
8	Structure consideration and material selection
9	Tolerances and fitting selection
10	Tooling and machining
11	Product testing