Creativity Cultivation through Early Design/Build Opportunities for Freshmen Engineering Students

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Abstract — *This paper presents an overview of the introductory course " Introduction to Mechanical Engineering" at Yuan Ze University, a required course for freshmen engineering students in Mechanical Engineering. The objective of this course is to provide a broad base for students in mechanical technology, as well as fostering creativity and hands on experience. The three credit course is evenly divided according to the prescribed focus and integrated with the DIY units by using a design kit. The contents of this course are briefly outlined and the implementation scheme for DIY units is also presented in this paper. The results of a class survey showed a high correlation between student expectations and the teaching objectives of this course.*

Index Terms — *Creativity, Design, Mechanical Engineering*

INTRODUCTION

The implementation of the Accreditation Board for Engineering and Technology (ABET) Engineering Accreditation Criteria 2000(EAC 2000) into the Mechanical Engineering undergraduate curriculum is critical to the success of the education program. The EAC Criteria 2000 emphasizes an outcome based systematic approach to engineering education. The basic level of criteria for the engineering program outcome and assessment requires graduates to demonstrate abilities (a-k) [1], in math, science, engineering, design, teamwork, ethics, communication and life-long learning. At Yuan Ze University, this is being implemented using a series of hands-on and early-design projects during the freshman year. In addition to the ABET accreditation criteria 3(a-k) requirements, the program was also designed to cultivate the "creativity" of participating students. In order to meet these challenges, a three-credit compulsory course, "Introduction to Mechanical Engineering", was used as a teaching platform. The three-hour course was divided evenly into three units, technology, creativity and DIY (Do it yourself), respectively. The technology unit was mainly covered by the introduction of advanced mechanical technology such as electromechanical systems, precision machinery and nanotechnology. Contents of the creativity unit included introducing the design process as well as the methodology of creativity such as brainstorming and so on. Finally, teams of five to six students were formed and issued a tool kit developed by Fischertechnik. A series of projects were then assigned to each team and they were asked to develop several design alternatives to meet design criteria. As part of the ongoing implementation activities at Yuan Ze, we also condensed and modified some of the course content into units that can be used for fifth grade students in elementary school. This initiative has been well received by students, and offers an engaging and instructive method to introduce students to design, engineering technology and the dynamics of teamwork.

This paper will discuss the development and implementation of the three credit course from conception through to implementation. Specific topics, such as the DIY unit, the response from students and lessons learned during the implementation of the program, will be addressed.

COURSE IMPLEMENTATION

Yuan Ze University has always claimed to be an experimentalist in higher education. Since the university was established fourteen years ago, we have created many innovative education models with unique features, and our achievements have been praised and affirmed in many circles. The Mechanical Engineering Department at Yuan Ze University was established in 1989. Currently there are 19 faculty members, more than 700 students (including undergraduate, master, and doctoral students), and more than 1300 alumni. The department seeks to combine excellence in education and research with service to society as a whole. The goal of our academic program in mechanical engineering is to provide students with a balance of intellectual and practical experiences that will enable them to address a variety of societal needs**.** Our program at the undergraduate level emphasizes creativity**,** hands-on experience**,** internationalization**,** and the ability to adapt to experience**,** internationalization**,** and the ability to adapt to rapidly changing technologies**.**

The course, Introduction of Engineering（EG101）is divided into three main parts：(１) Mechanical technology (２)

Creativity cultivation and （3） DIY hands-on projects.

（1） **Mechanical technology**：there are several topics introduced under this part of the course.

（**a**）**Overview of mechanical engineering**

Engineering is the art of applying scientific and mathematical principles, experience, judgment, and common sense to make things that will benefit people. Engineers are problem solvers, people who search for quicker, better and less expensive ways to use the forces and materials of nature to meet tough challenges. The progress of mechanical engineering is briefly introduced from earliest recorded times to the present day. The highlights of the history of mechanical engineering are outlined in this section.

（**b**）**Status and outlook of mechanical engineering in Taiwan**

The development of mechanical engineering in Taiwan is introduced in this section. By referring to customs' export/import statistics, the total export/import value of the mechanical industry is outlined. The production values of different types of machinery from local manufacturers, as well as from exporting/importing countries are reported.

（**c**）**How do things work? Simple machines**

A machine is any device that helps people to do work, transform, multiply force or multiply speed and change the direction of a force. There are only six simple machines: the lever, the block and tackle, the wheel and axle, the inclined plane, the screw, and the gear. Physicists, however, recognize only two basic principles in machines: those of the lever and the inclined plane. The wheel and axle, block and tackle and gears are considered to be levers. The wedge and the screw use the same principle as the inclined plane. The basic principles of these simple machines are introduced in this section.

（**d**）**Mechatronic I－Mechanisms, machine components**

A mechanism is the mechanical portion of a machine that has the function of transferring motion and force from a power source to an output. It is the heart of a machine. A mechanism can be made up of rigid parts that are arranged and connected so that they produce the desired motion of the machine. The various machine components that are commonly found in basic mechanisms are introduced, such as the bolt and nut, shaft, bearing, gear and valve.

（**e**）**Mechatronic II－Motion control system**

A modern motion control system typically consists of a motion controller, a motor driver or amplifier, an electric motor and a feedback sensor. The system can also contain other components such as one or more belts, ballscrew or leadscrew-driven linear guides and axis stages. Today, a motion controller can be a stand-alone programmable controller, a personal computer containing a motion control card or a programmable logic controller（PLC）. All of the components of a motion control system must work together seamlessly to perform their assigned functions. Their selection must be based on both engineering and economic considerations. Some applications of motion control systems are introduced here.

（**f**）**Mechatronic III－Hydraulics/Pneumatics**

What is fluid mechanics? As its name suggests it is the branch of applied mechanics concerned with the statics and dynamics of fluids - both liquids and gases. Analysis of the behavior of fluids is based on the fundamental laws of mechanics which relate continuity of mass and energy, to force and momentum, together with the familiar solid properties of mechanics. The applications of fluid mechanics as well as air dynamics, such as hydraulics or pneumatics are highlighted in this section.

（**g**）**Thermal science and its applications**

A major application area of thermodynamics is the conversion of disorganized energy (heat) into organized energy (work). Organized energy can be converted to disorganized energy completely, but only a fraction of disorganized energy can be converted to organized energy. In many thermodynamics problems, mechanical work is the only form of work involved. Some common forms are moving boundary work, gravitational work, accelerational work, shaft work and spring work. Thermal machines such as the four stroke engine, the jet engine and the air conditioner are introduced in this section.

（**h**）**The impact of information technology : CAD/CAE/CAM**

The term CAD/CAE/CAM system typically refers to a computer interactive graphics system equipped with software to accomplish certain functions in design, analysis and manufacturing. CAD can be defined as any design activity that involves the effective use of the computer to create, modify or document an engineering design. CAE is most commonly associated with the use of computational mechanics to simulate the real response of the product. CAM is defined as the effective use of computer technology in the planning, management and control of the manufacturing function. Several examples, such as a tool design process using Pro/E and Ansys software are introduced in this section.

（**i**）**The future of mechanical engineering I : Microtechnology**

Microtechnology has enabled the fabrication of micron-scale mechanical devices. It attempts to make bulk-material structures smaller despite fabrication irregularities. Most microfabrication technologies originated from the semiconductor industry and are introduced in this section. The topics include photolithography, etching, deposition and diffusion.

（j）**<u>The future of mechanical engineering II: Nanotechnology</u>**

Manufactured products are made from atoms, and their properties depend on how these atoms are arranged. The use of nanoscale mechanical systems to guide the placement of reactive molecules by building complex structures with atom-by-atom control is introduced. Compared to Microtechnology, molecular manufacturing is emerging from attempts to make molecular structures larger, without losing the atomic precision characteristics of stereospecific chemical synthesis.

（k）**<u>The future of mechanical engineering III: Clean Energy</u>**

Electrochemical fuel cells hold the promise of efficient, quiet and pollution-free power generation with a wide applicability. Except in special cases like spacecraft, today's fuel cells are outperformed by the energy converter they seek to replace, whether it is an internal combustion engine for automobiles or a fossil-fueled generator. However, fuel cells achieve the multiple goals of converting energy resources and reducing pollution, emission of greenhouse gases and waste heat. The future application of fuel cells in mechanical engineering is introduced in this section.

（2）**Creativity cultivation**：In this part, problem solving skills and the introduction of innovation and creativity are emphasized. Creativity is the process of being creative, in which new ideas, thoughts and physical objects are brought forth. Students are therefore encouraged to learn creative problem solving skills and make use of them. Some of these skills are discussed under this topic.

（a） **Brainstorming**

Alex Osborn, an advertising executive, introduced brainstorming in 1941 during a conventional business meeting. He described brainstorming as 'a conference technique whereby a group attempts to find a solution for a specific problem by amassing all the spontaneous ideas of its members.

Since its beginnings in 1941, brainstorming has spread throughout the world. The technique is known, but is often not applied effectively, because of poor training and lack of access to quality training materials. We have therefore trained our students to use brainstorming in class and share their ideas in weekly assignments and DIY lessons. Before beginning, students were taught the principles behind brainstorming.

（I）**Removing the fear of making mistakes**

Brainstorming is designed to reduce or even remove the fear of making mistakes. Everyone has thousands of good ideas just waiting to be expressed. So, making 'mistakes' and putting forward ideas that don't work is not only acceptable, but encouraged in the brainstorming environment.

（II）**Postponing and withholding judgment**

Ideas should be put forward both as solutions and also as a basis for finding solutions. Even a seemingly foolish idea can initiate a better one. Therefore, one should not judge an idea until after the brainstorming process has ended. All ideas should be made note of as each is worthy of consideration.

（III）**Encouraging wild and exaggerated ideas**

It is much easier to tame a wild idea than to think of an immediately valid one. The 'wilder' the idea the better as no idea is ridiculous. Students are encouraged to come up with outlandish ideas and exaggerate them to the extreme.

（IV）**Quantity counts at this stage, not quality**

All activities should be geared towards extracting as many ideas as possible in a given time. If the number of ideas at the end of the session is very large, the chance of finding a really good idea is greater.

（V）**Build on the ideas put forward by others**

Building and expanding on the ideas of others is encouraged. The ideas of others should be used as inspiration to develop your own. It is just as valuable to be able to adapt and improve other people's ideas as it is to generate the initial idea that has set off a new train of thought.

（VI）**Every person and every idea has equal worth**

Every person has a valid viewpoint and a unique perspective on a situation. Each idea presented belongs to the group and not to the person who first thought of it. Brainstorming is a group responsibility and an indication of the success of the group is the free and confident participation by all.

<u>In class practice: *How to make students come to school on time?*</u>

Students are given 10 minutes to brainstorm, coming up with as many solutions as possible to solve the problem. Then, they note down their ideas on the work sheet provided and when the time is up, each group sends a volunteer to present their outcome. The more ideas they came up with, the higher their score.

（b） **Wishful thinking**

Wishful thinking is one of the methods among the attributes listed. Wishful thinking encourages one to imagine the way one wishes the product could be and then to use this "wish-list" as a creative stimulant for improvements or new ideas. In other words, wishful thinking has you imagine a new idea for a product in order to be able to create that product.

（c） **Checklist method**

This is a methodical way to consider known products. Students list out all the possible factors or conditions associated with a given product, check and discuss each of these factors very carefully, and then delete irrelevant points. In this way, the factors remaining will be the main points for discussion.

（d） **Attribute listing method**

Attribute listing is a great technique for ensuring that all possible aspects of a problem have been examined. It breaks down the problem into smaller parts and allows a more in depth analysis.. This technique is very useful for quality improvement of complicated products, procedures and services. It is an excellent technique to use in conjunction with other creative processes, such as brainstorming. It allows you to focus on a specific part of a product or process in order to generate more ideas.

In class practice: *How to improve a traditional screwdriver?*

First of all, students would consider and then write down the defects inherent in a traditional screwdriver. They would then have to choose one or more of the factors which could be easily improved. Finally, they would begin the process of how to implement the improvements.

（e） **Fishbone diagram（Scatter diagram）**

Another name for a fishbone diagram is a cause and effect diagram. It is an analysis tool to display the possible causes of a specific problem or condition. This diagram is used for （i） identifying the potential causes of a problem or issue in an orderly way and （ii）summarizing the major causes under four categories such as methods, machines, materials and people.

（3）**DIY Hands-on projects**：In the course EG101, besides the teaching of engineering theories and creative problem solving, we also included hands-on lessons, called DIY, to help students make use of the theories they had learned, with time to practice. We chose the Fischertechnik products as our teaching materials in the DIY projects.

Fischertechnik is a family of construction kits that allow realistic working models to be assembled. The Fischertechnik system was developed by Fischerwerke, a major German manufacturer of industrial fasteners. In order to make DIY hands-on practice more interesting, we brought in sets of products manufactured by Fischertechnik.

FIGURE 1: FISCHERTECHNIK PROFI SENSORIC

FIGURE 2: FISCHERTECHNIK PROFI PNEUMATIC

FIGURE 3: FISCHERTECHNIK FOCUS SERIES

(1) Profi Sensoric：Distributorless switching and automation with sensors. Hand drier, cash dispenser, sorting machine - this kit contains realistic models that show you how to operate and automate devices. Contains FLIP-FLOP, photo transistor, read distributor, NTC resistor, switch, S-Motor, gear and 9V battery holder. More than 380 parts.

(2) Profi Pneumatic：An exciting adventure into technology in a game. The Pneumatic kit is completely equipped with a mini-compressor, 6 cylinders, 4 rotary plug valves and 9v battery holder. More than 530 parts.

(3) Focus Mechanisms Kit：The Mechanisms kit offers a wide range of mechanical systems, including: rotating movements, power transfer, gear systems (crown gears, beveled gears, worm drives, plate-wheel gears etc.), conversion of rotating into linear movements - toothed racks, spindles, conversion of rotating into to-and-from and swinging movements - cams, pusher cranks, crank oscillations, chains, belt pulleys and belt drives. The subject matter also includes the basic mathematical theory of reduction gears and speed relationships, the laws of levers and levels of efficiency.

(4) Focus Structures Kit：Quickly built simple static models enable for student to gain knowledge of the laws of static forces.

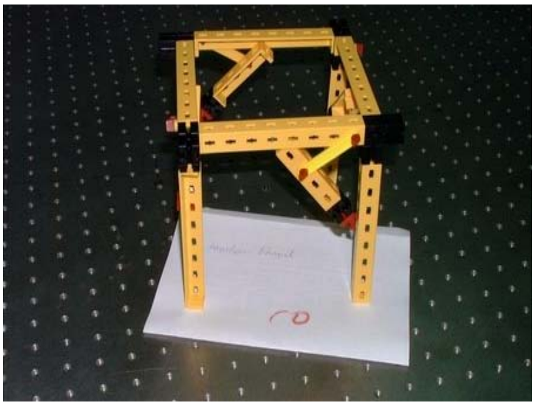
(5) Focus Electrical Control Kit：This kit contains a motor, gears, switches, lamps, wiring with push-in connections and various basic Fischertechnik components. A 9V power supply is also necessary.

Students use the Fischertechnik sets mentioned above to complete their DIY hands-on practice every week. There are 5 units for DIY hands-on practice：

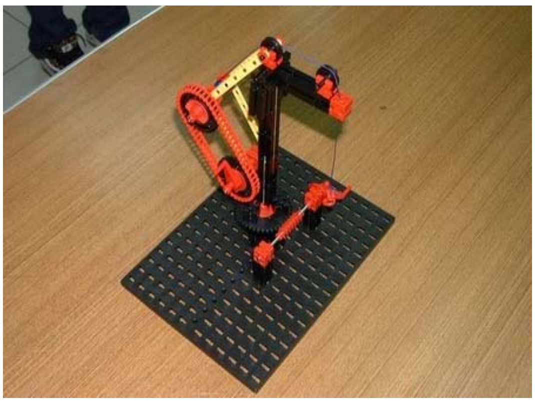
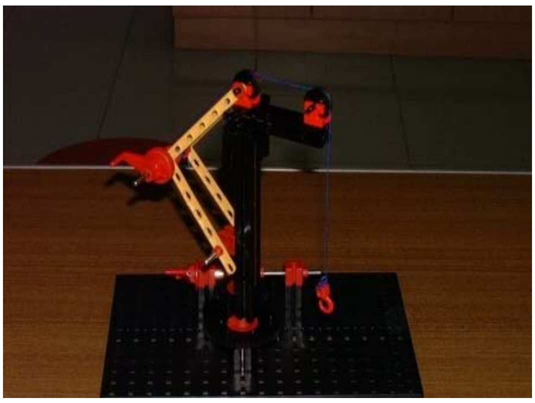
(1) Desk
(2) Hoisting system
(3) Vehicle
(4) Transportation device
(5) Mechanical engineering

STUDENTS PRODUCTS

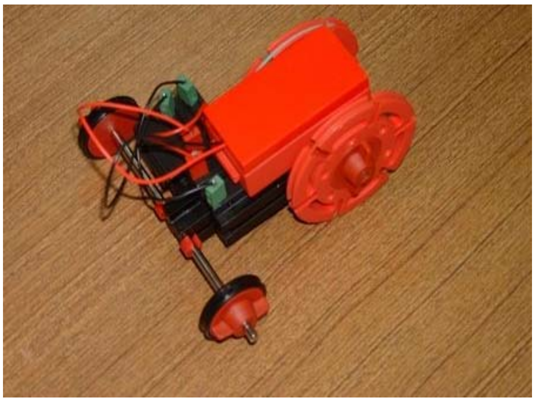
(1) Desk (Using Fischertechnik－Focus Structures Kit)

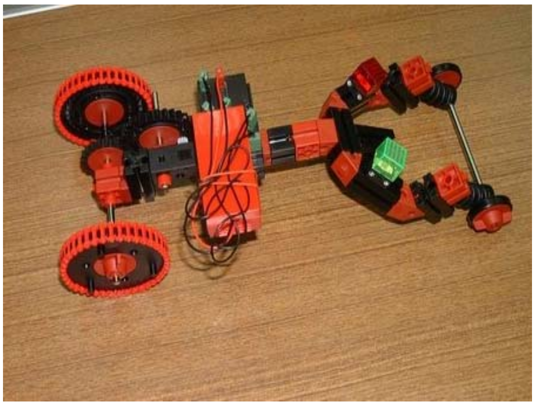



(2) Hoisting system (Using Fischertechnik－Mechanisms Kit)

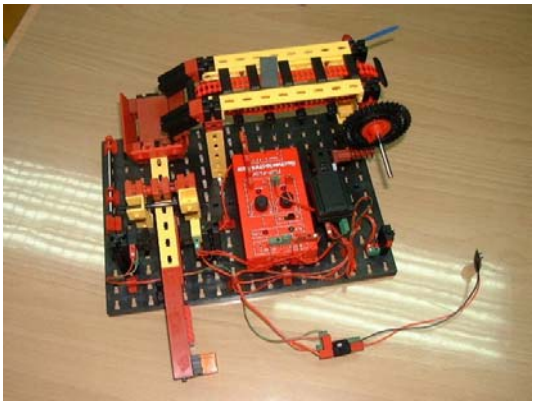



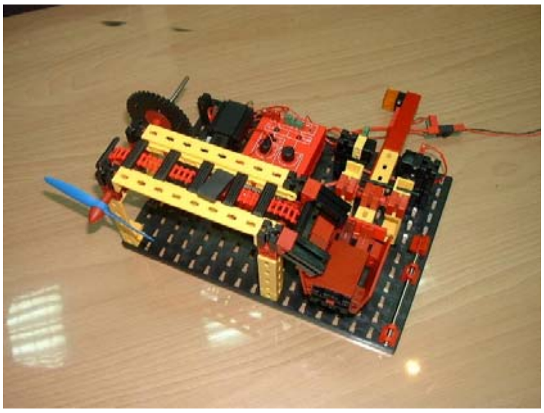
（3）Vehicle（Using Fischertechnik－Electrical Control Kit ）





（4）Transportation device（Using Fischertechnik－Profi Sensoric ）





（5）Final Assignment（Using Fischertechnik－Profi Pneumatic ）

EVALUATION

The evaluation of course EG101 is divided into four parts. These are 10% for each of the five DIY units, 15% for assignment I, 20% for the final assignment and 15% for the midterm and final exam. We also do a survey to determine how satisfied the students are with the course. The results of the survey are as follows:

TABLE 1:
LESSON SATISFACTION SURVEY

		agree	No comment	disagree
1.	The teaching materials and lesson content are suitable.	34	3	1
		89.47%	7.89%	2.63%
2.	The lesson content is satisfactory in both quality and quantity.	32	6	
		84.21%	15.79%	
3.	The lesson outline was well organized and planned in order to assist students in learning the material.	31	7	
		81.58%	18.42%	
4.	The teacher explained difficult theories in simple language and followed up with easy to understand examples or teaching materials.	29	8	1
		76.32%	21.05%	2.63%
5.	Grading of the course was satisfactory.	30	8	
		78.95%	21.05%	
6.	Course requirements such as assignments, reports and tests were satisfactory.	18	20	
		47.37%	52.63%	

*N=38

The lesson satisfaction survey was specifically designed for the EG101 course to find out how satisfied the students were with regard to the content, the teacher's skill, the outline of the lesson and the teaching materials used. There were 38 students in the course.

Thirty four students agreed that the content of the teaching materials used in the course were suitable, 3 had no comment and 1 person disagreed.. This result showed that the teaching materials used in this lesson are suitable and appropriate to the students' needs. It also assisted in the students' learning. The results of the survey on the content of the lesson showed that 32 students agreed that the outline of the lesson was well organized and planned in such a way as to help students learn. For teaching performance, 29 students agreed that the teacher always explained difficult theories in simple terms and sometimes followed up with examples or teaching materials, to help student understanding.

As far as course grading was concerned, there were 30 students who felt that the grading of the course was satisfactory, but only 18 agreed that the requirements of the course were satisfactory.

In conclusion, most of the students agreed that regardless of how they felt about the planning of the course, the teacher's performance, the use of teaching materials or even the grading of the course, they were highly satisfied with the course overall.

CONCLUSION

We feel that the reorganization of the course content has been a success on several fronts. The students have become more excited about mechanical technology and the potential benefits of its application. The technological challenges in the related areas cover a wide spectrum of engineering fields so that the students have the information required to plan for their next four years. We feel that the units involving the cultivation of creativity combined with the DIY units give the students a true sense of what it means to collaborate as a team while working on the challenge of the design process. As well as acquiring technical knowledge, students have gained valuable experience in teamwork, communication skills, project planning and public relations.

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