Global J. of Engng. Educ., Vol.5, No.2
Published in Australia

A Project Design and Implementation Programme for Industrial Technology Teachers

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For several years, both students and professors have taken a unique course at the National Changhua University of Education (NCUE), in Changhua, Taiwan, in the College of Technology. The course, titled *Project Design and Implementation*, is offered by the NCUE's Department of Industrial Education. The purpose of the Department is to prepare future industrial vocational teachers. On the other hand, there are two categories of faculty members in the Department: engineering and industrial education. Constant cooperation between the engineering faculty and technology students makes the course a shared responsibility event. Engineering faculty are more interested in the design concepts and engineering mathematics while the technology students are more interested in the management of programmes and the hands-on activities of manufacturing. Over past years, students have created hundreds of projects and many are still in use by the industrial and educational sectors. The students developed all the brochures, videos, photographs, product testing and even the logos. They met their targeted manufacturing costs, which real world companies cannot often achieve.

INTRODUCTION

The purpose of this paper is to present a uniquely coordinated programme developed in Taiwan, which promotes the preparation for future industrial technology teachers, vital for improving the educational standard. In a rapidly growing society like Taiwan, traditional training approaches and procedures have to be upgraded and enhanced in order to meet the developing needs of modern industry.

Several technology-oriented universities in Taiwan have established certain curricula to serve this purpose. *Theory into practice* has been a slogan around Taiwan; this reveals the urgent need for change. However, many of the Taiwanese college students have experienced difficulties in applying the basic theory and analytical methods discussed in their related engineering courses to the design tasks in their senior design course.

To counter this, a course titled Project Design and Implementation (PD&I) was developed in the Department of Industrial Education at the National Changhua University of Education (NCUE), located in Changhua, Taiwan. It has so far proven to be quite successful across several dimensions.

THE IMPACT AND THE CHALLENGE

Due to the long-term macroeconomic imbalance and the rapid political and social changes brought about by the 1986 lifting of martial law, Taiwan's industrial competitiveness has declined, and with it, its exports. Labour-intensive industries have gradually lost their comparative advantage and moved abroad for investment and production, partly due to the changes in the domestic investment environment in recent years. At the same time, technology-intensive industries have experienced strong growth and show a substantial improvement in the industrial structure [1]. Furthermore, the impact from Taiwan's future membership in the World Trade Organisation (WTO) has resulted in calls for faster industrial upgrading.

Researchers have recognised other apparent changes, including that workers are expected to solve problems, seek ways to improve the methods that they use and engage actively with their co-workers in modern high-performance workplaces. It will be risky for many skilled workers to simply perform well-defined tasks and leave anything out of the ordinary to their managers or specialised support personnel [2-4].

Future vocational industrial teachers are now faced with the challenge of guiding students in vocational high schools to equip themselves with initiating capabilities. The standards of skills appear from a different viewpoint that now focuses on the reform of vocational education and on preparing students for work in modern workplaces [4][5]. The PD&I programme has responded to this challenge.

TECHNICAL EDUCATION IN TAIWAN

Common Errors of Student Projects

The following are common complaints about student projects/products from a renowned engineering college in Taiwan:

- Inability to formulate concepts, nor to translate concepts into analytical terms, ie inability to solve practical problems.
- Lack of physical insight and hands-on experience.
- Lack of motivation, self-confidence and self-respect in exploring new territories.
- Lack of motivation and discipline to guarantee the quality of works by verifying the results and thinking through ideas critically.
- Lack of flexibility to employ a versatility of knowledge to solve problems from a holistic system point of view.
- Inability to convey ideas effectively and to work collectively as a team in order to bring out the best of all members involved [6].

Other common unfavourable phenomena of student project design and implementation include:

- Confusion on physical units of measurement (UI vs. British vs. other unit systems).
- Lack of confidence in presenting data (when data show no significant difference).
- Homemade style (lack of real-world quality).
- No proper transfer of ideas (fragmented continuum of certain great ideas).
- Too much too fast (trying to solve many problems all at once).
- Poorly written instructions/descriptions.
- Lack of commercial value.

All these drawbacks could happen in part, or at times in majority, although students had been instructed to avoid them. Many cases could be susceptible to the limitation of allocated time, while more could be attributed to the lack of real-world experience. Causes of problems could be categorised as follows:

- Unavailability of material, equipment, machine tools or techniques.
- Inadequacy of systems approach.
- The *if it works, it is okay* mentality.
- Lack of references to industrial standards.

Coping Strategies

Writing a proposal for the project can be hard work. On the syllabus of the course, students are given the following guided procedures before they actually get started:

- Carefully identify and verify a need for the project.
- Brainstorm with those who may be affected by the project.
- Find out if anyone else is planning a similar project. If so, explore the possibility of collaboration.
- Invite related professors/off-campus experts to form a small advisory group.
- Develop a practical timetable.
- Obtain examples from other institutions before developing the tentative project.
- Search for a funding source if the situation permits.
- Submit the proposal on or before the deadline.

Evidence shows that these procedures do, indeed, help students in constructing a firm grasp of the whole initiative, which benefits them in their subsequent actions. Instructors of this course also try to provide examples of student projects from various advanced countries. Even the non-confidential technical orders from the military are collected as supplementary texts.

Although efforts have been made to reduce the risk of unsuccessful commencement, a number of groups may still fail to develop a viable timetable due to inexperience, resulting in an unexpected lag in progress. However, such unfavourable consequences are also part of the overall learning experience.

INTERDISCIPLINARY COLLABORATION

There are five groups of specialties in the NCUE’s Department of Industrial Education. These cover the fields of:

- Electrical engineering;
- Electronic engineering;
- Mechanical manufacturing technology;
- Mechanical design;
- Vehicle technology.

With over 600 undergraduate and graduate students in different courses of education, the Department educates not only future industrial teachers but also engineers and technologists [7]. These groups often work interactively towards some special projects funded by the Taiwanese government, as well as cooperative industries known as *Mechatronics* [8]. This is shown in Figure 1.

Students and related faculty members meet and discuss regularly to search and solve problems that arise from real-world settings. Sometimes a special taskforce, formed by the Department head, may be appointed to correct potential or critical errors. When solving intricate problems, integration is the key. More than a dozen persons with engineering doctorates have joined the Department in recent years. They help industrial (technology) education students deal with engineering problems while the students help manage the project and especially contribute to the hands-on experience.

University-Industry Cooperation

Local industry is an excellent resource of extra-curricular learning. A mutually beneficial cooperative programme has been around for years taking the advantage of expertise exchange. Some company CEOs are graduates of the NCUE, and are proud of being helped, and more often helpers. To those distinguished companies, the collaborative programme acts as a bridge linking the *ideal* world and the *real* world together.

In addition to offering of challenging projects, industry also provides financial support, advanced facilities, better technologies, different concepts and, most importantly, the environment and chances to work with real practitioners. In return, the University sets up academic advisory committees, assigns skilful students and even research findings to industries.

Three-month full-time field experience plus ongoing partnership provide opportunities not just for students to learn, but also for companies to *observe*. Some Industrial Education graduates with special talents or licenses had been recruited to work in industry before they became teachers. However, graduates find teaching in industrial schools their favourite career. Since many of them are medal-winners of national or international skill contests, they are often appointed as coaches/trainers by schools as well as the industry. Graduates with patented or awarded projects are even more popular in both job markets.

FEATURES OF THE PROGRAMME

Most teachers are familiar with Bloom et al's *Taxonomy of Educational Objectives: Cognitive Domain* and the different levels of the cognitive domain that it identifies [9]. The major activities and typical tasks of the PD&I programme involve the three higher levels of the cognitive domain: analysis, synthesis and evaluation. This is on top of the three lower levels: knowledge, comprehension and application.

Over the past years, different models and concepts have been taught to students. One of the theories adopted by some instructors is Wilcox's model, shown in Figure 2 [10]. The two elements of project plan and project implementation serve different purposes while corresponding with each other in several stages. One might think that the activities of both areas are almost identical. However, when students carry out the project, they are *doing* the technical design and the prototype construction rather than *talking* about doing it.

No single standard instructional model is enforced in the Department in order to avoid being near-sighted, analytical and uniform. A generally accepted principle is to encourage students to have a vision, develop their evaluation skills and become creativity-oriented.

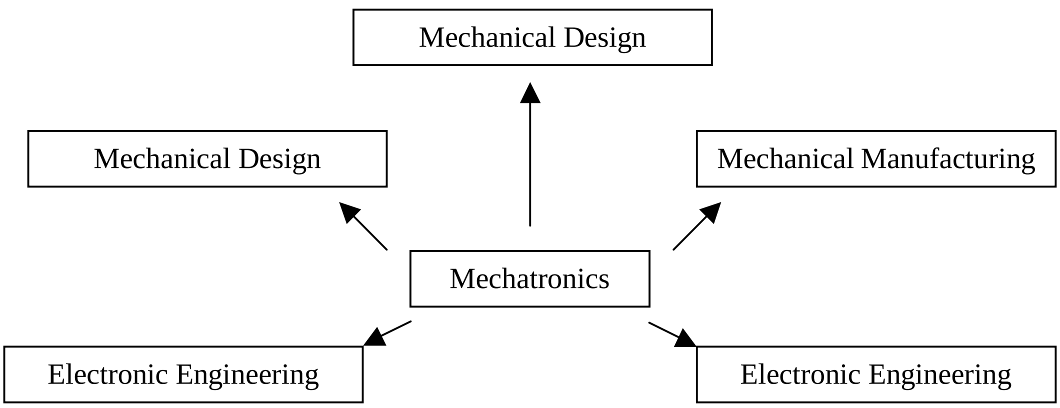

Figure 1: *Mechatronics* as a joint effort.

Project plan		Project implementation
Project definition		
Goal of the project		
Project objectives	→	Analysis
Specifications		Specifications
Constraints		Constraints
Assumptions		Assumptions
Strategy	→	Synthesis
Idea of how to solve the design problem		Generate design concept
Plan of action	→	Technical design
List tasks (design, build, test)		Do various tasks
Schedule tasks		
		Evaluation and decision
		Prototype construction
		Evaluation
		Documentation

Figure 2: Wilcox's model of project plan and implementation.

Similar to artistic design, industrial design is the intended arrangement of materials to produce a certain result or effect. Students are encouraged to help make products attractive, as well as easy to use and maintain.

The design phase is often critical for success or failure of a project. Therefore, models of design processes are sometimes taught separately. The simplified model shown in Figure 3 is one of the selected processes [11].

Senior students are usually the busiest as many heavy courses are at their culminating stages. Thus, in the process of instruction, some engineering compendia are useful for students *to increase the design content in their courses without having to expend major effort, reorganise the courses or displace current materials* [12].

Knowledge of human factors has been delivered to students especially on the types of information presented by displays. Students learn to identify and select appropriate types information, such as quantitative, qualitative, status, warning and signal, representational, identification, alphanumeric and symbolic, and time-phased information.

Some special practices applied in industries, such as reverse engineering (RE) and design for X (DFX), have been tried by some project teams. The RE approach shown in Figure 4 is found to be quite common in local industries.

The idea of X = x+bility (life cycle business process + performance measures) by Huang has intrigued several faculty members in the Department of Industrial Education [14]. It is practical as well as educational. X in DFX stands for many (in fact, any) aspects a designer can come up with. For example, let *x* = *total* and *bility* = *quality*, it turns out *design for total quality*. Other key words can include lifecycle, assembly cost, purchasing, fabrication, material logistics, material handling, inspection and test, installation, recycling, disposal, etc. It will be beneficial for future industrial teachers to establish the concepts of manufacturability, inspectability, recyclability, flexibility, etc, if they can contribute to the upgrading of industry in Taiwan.

Highlights of Student Projects

More than 190 projects have been accomplished in the past five years, with most projects being human-machine systems. If categorised by the degree of manual versus machine control, there are three broad classes: manual, mechanical (semi-automatic) and automatic [15]. All three classes of systems are found in students' projects.

The evaluation of the PD&I programme takes into account both formative as well as summative processes. The aesthetic aspects such as repetition, harmony (or balance), contrast (or discord), rhythm and movement, and unity are also considered. However,

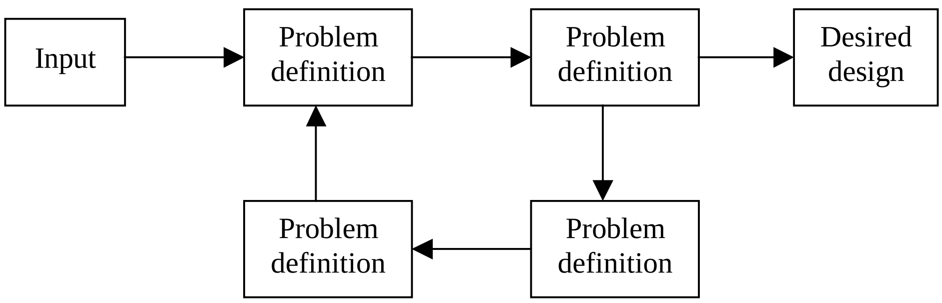

Figure 3: Bahrami and Dagli's model of design processes.

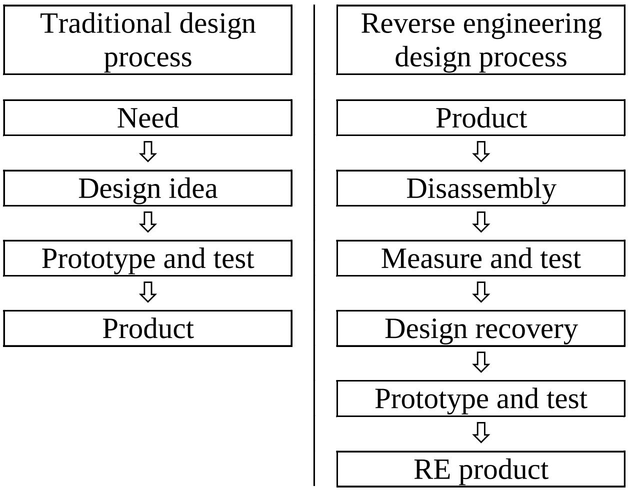

Figure 4: Traditional versus reverse engineering design processes [13].

as an engineering project and with its problem-solving nature, the PD&I programme often stresses the result of *how well does it work?* This is a common key question asked at the consummation stage.

In the past five years, student projects have been categorised according to their stated functions (purposes) as shown in Table 1.

Although not evenly distributed, students and instructors often try to work out a somewhat balanced list to attract an audience from different sectors at the Project Show held in June every year. In addition to vocational school principals, many executives from industrial sectors, educators and governmental officials are invited to tour the show and participate in a seminar.

There have been failures, inevitably due to accidents, lack of good communication, inadequate procedures, inability to meet deadlines, etc. Nevertheless, if formative evaluation records show that those students have tried their best then they are allowed to make up within a designated time.

Theoretically, for those successful project teams, an informal questionnaire regarding needs of motivation showed that they were motivated by the following factors (in descending order): desire to achieve, challenge, professional status, pride in accomplishment, recognition, self-expression and creativity, independence and practice of technical knowledge and skills [21]. These factors are again confirmed by the observation of this programme.

WHAT LIES AHEAD?

For the second half of 1999 and all of 2000, the national budget for science and technology was NT$70.624 billion (US$ 2.053 billion) [1]. Despite the emerging service industry, a total average of 3,442,000 workers were still in goods-producing industries. A great portion of the budget has been invested in human resource development. Other data from the National Statistics Office shows that 37.23% of people under 30 were working in industries [22]. In terms of the labour force participation rate by educational attainment in Taiwan Area, 61.44 % were graduates from colleges and graduate schools.

Despite the heavy investment from public and private sectors, many talented young people are hindered from the professional world of work because of the lack of concrete hands-on skills. Obviously, a well educated yet practically trained younger generation is the most valuable asset that any society could have.

CONCLUSIONS

Today's universities and colleges are practically in the *service business* to supply constructive human resources for the society to meet both current and future needs. Any project/product should bear a somewhat long-term warranty. Student projects/products

Table 1: Stated functions (purposes) of student projects (1997-2001) [16-20].

Category	1997	1998	1999	2000	2001
Experimental product/process	7	3	3	3	4
Teaching aid, CAI, etc	7	6	3	5	6
Social services	4	3	2	4	3
Environmental preservation	3	1	5	2	3
Household improvement	4	2	1	3	4
Security and protection	5	1	2	3	4
Mock-up for gov. references	1	1	1	2	1
Industrial applications	17	18	10	14	14
Entertainment and exercise	-	1	1	2	-
Miscellaneous	-	1	1	-	1
Total:	48	37	29	38	40

shall not only be of current services but also the mechanism to bring about future breakthroughs, both technologically and sociologically.

Many Industrial Education alumni from the NCUE's Department of Industrial Education have switched back and forth between educational and industrial sectors. Still, they take the Project Show as the Department's reunion day to celebrate and treasure the commendable programme.

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BIOGRAPHY

Chih-Feng Chuang is a Professor in the Department of Industrial Education at the National Changhua University of Education in Changhua, Taiwan. He completed his BE degree at the same University. In 1984, he earned his MA degree from Truman State University, the USA, and his PhD in 1992 from Indiana State University in the USA. Before entering the higher educational sector, Prof. Chuang had worked for Yamatake-Honeywell Co. Ltd. (Taiwan) as a sales engineer specialising in refrigeration and air conditioning.

His current research interests include energy conversion/conservation, project management and the application of computer simulation in instruction. He has been attending engineering/technology education related conferences regularly since 1993.