TECHNICAL RESEARCH REPORT

Teaching New Product Development through a Product Engineering Approach

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ABSTRACT

This paper describes experiences gained in teaching a new course aimed at providing junior-level undergraduate engineering students with some of the fundamentals needed in developing new products. A six-stage engineering approach to develop a new product is proposed. Through a cooperative education partnership arrangement with Black & Decker, a new product is introduced to the class. Engineers from this corporation present a series of lectures on some their real-life experience with this product. The students work as teams to complete assigned course projects related to the new product development. During the redesign, Pro/ENGINEER and a method of rapid prototyping are introduced. These tools aid the students in inventing new components and in visualizing their ideas in the learning process. An extremely positive response from the participating students reflects upon the innovative approach developed in this course.

I. INTRODUCTION

Today's business climate is characterized by the competition for the market of manufacturing goods. To survive and succeed in the competition requires corporations to provide new products with superior quality at an acceptable price. Recognizing the high cost involved in developing new products, more corporate efforts have been put into recruiting new and young engineering graduates who demonstrate the promise and potential to achieve the defined corporate business strategy. As a result, the corporate recruiting process has become more demanding and selective. On the other hand, the increase in college tuition and the desire to start their professional careers as early as possible are driving college students to take those academic courses which provide knowledge and hands-on experience current with latest technologies and practices in the workplace. These facts and trends from both the corporations and students have placed tremendous pressure on engineering educators to constantly improve the content and delivery of educational materials to ensure a valuable engineering education for students.

As a national effort, engineering educators are trying to teach college students not only theory and fundamental principles, but practical applications as well. There have been many successful stories. Sorby and Baartmans, and Leach and Rajai developed courses in engineering design for freshman and sophomore students where the teaching of 3D spatial visualization and computer aided design were integrated to provide participating students with a comprehensive understanding of fundamentals of engineering design [1-3]. An engineering design course developed for freshman students at the University of Maryland emphasized an early introduction of engineering design in the engineering curriculum [4-5]. In an effort to provide a systematic approach, Bertoline, et al. proposed a conceptual model for the engineering graphics curriculum in which key factors, such as using 3D geometric models, applications and communications, were highly emphasized [6-7]. To integrate design and manufacturing, Barr and Juricic proposed the offering of integrated product and process design to better equip senior engineering students for the engineering job market [8-9]. It should be pointed out that the National Science Foundation has made unique contributions to leading this national effort. It provides a significant amount of funds to support the development of new and innovative curricula in engineering education and to support the creation of teaching and learning environments which best fit the needs of college students [10].

In this paper, we describe the experience gained from developing a new course offered to engineering students at the junior level. The main objective is to provide the students with the fundamentals of developing a new product. The course is entitled "Product Engineering and Manufacturing" [11]. It has become a part of a new mechanical engineering curriculum at the University of Maryland [12]. The course is taught through a cooperative education partnership arrangement with Black & Decker, one of the largest manufacturers of power tools in the world. Section 2 of this paper outlines the university-industry education partnership program. Section 3 presents the basic course structure and major activities of the teaching process. Section 4 is a collection of critical observations made during the teaching process. Finally, we present conclusions based on our experience gained from teaching this new course.

II. Cooperative Education Partnership with Black & Decker

The main objective of this course is to provide the students with a comprehensive understanding of a new and successful product development process. To explicitly define such a development process, we propose a six-stage approach, as illustrated in Fig. 1. It starts from the customer needs, functional requirements, development constraints, product design, product manufacturing, and finally product marketing. It is critical that these concepts of the new product development be current with industrial practice.

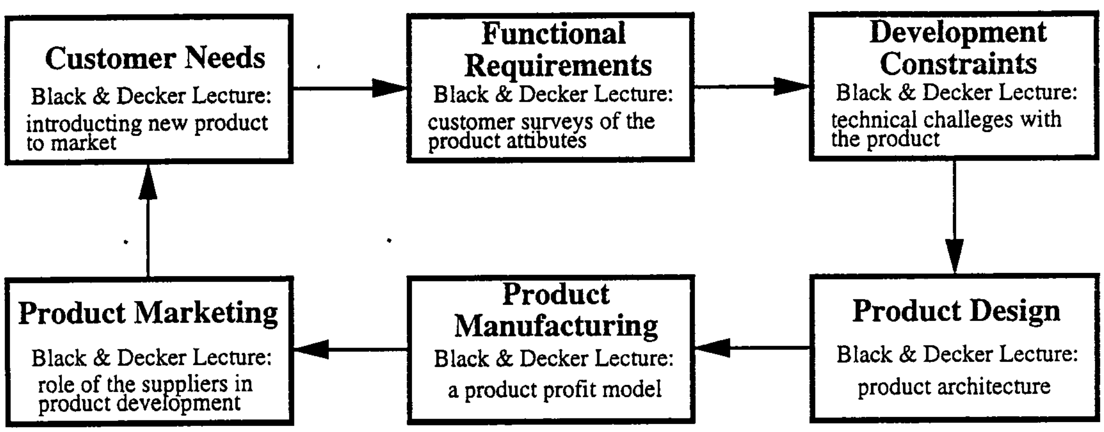


Figure 1 A Six-Stage Engineering Approach to Develop a New Product

In order to create a unique learning environment for students, the University of Maryland has established a cooperative education partnership arrangement with Black & Decker. Every year a newly developed product is introduced to the class. Before the semester starts, faculty members have meetings with Black & Decker managers and engineers involved in the new product development. Topics to be covered during the teaching process are discussed. Arrangements are made for Black & Decker engineers to present lectures in the classroom. Arrangements are also made for the students to visit the corporation. The instructor keeps in constant contact with the corporate engineers to ensure that the defined goals and objectives are met during the entire educational process.

III. Basic Course Structure

To demonstrate the basic course structure, the structure used in teaching this course in the fall 1996 semester is presented. Thirty students taking the course were organized into six teams. On a weekly basis, the students attended two one-hour lectures, either given by the instructor or by an engineer from Black & Decker. The students also met every Friday for a one-hour team meeting. Figure 2 illustrates major activities in terms of the classroom lectures, Black & Decker engineers' lectures, student team projects, and course evaluation.

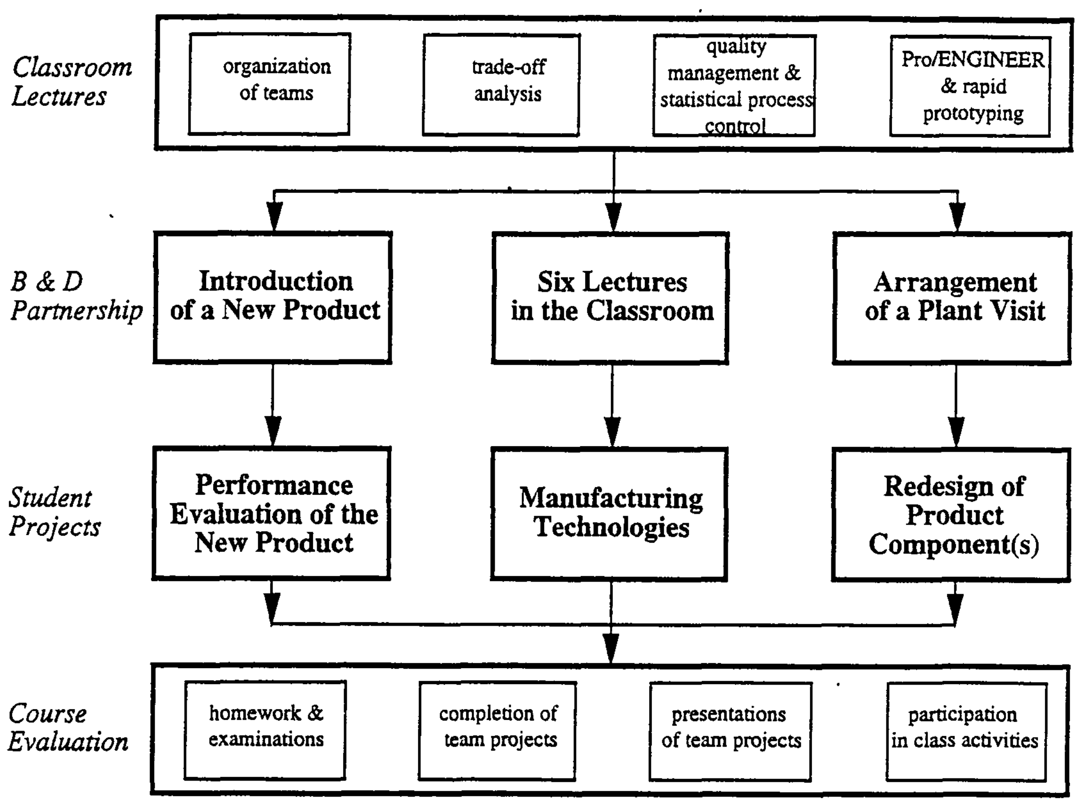


Figure 2 Basic Course Structure and Major Activities

The product introduced in the fall 1996 semester was a newly designed and manufactured screwgun by Black & Decker. At the beginning of the semester, each student team and the instructor received a screwgun from Black & Decker. Following the operational manual, the students and the instructor disassembled and assembled the screwgun to become familiar with the operational procedure. Figure 3 illustrates the screwgun and its components. Major components are an electrical motor, a gear transmission system, a clutch mechanism to drive an operational bit, a fan cooling system, a switch and a plastic clip for carrying the screwgun.

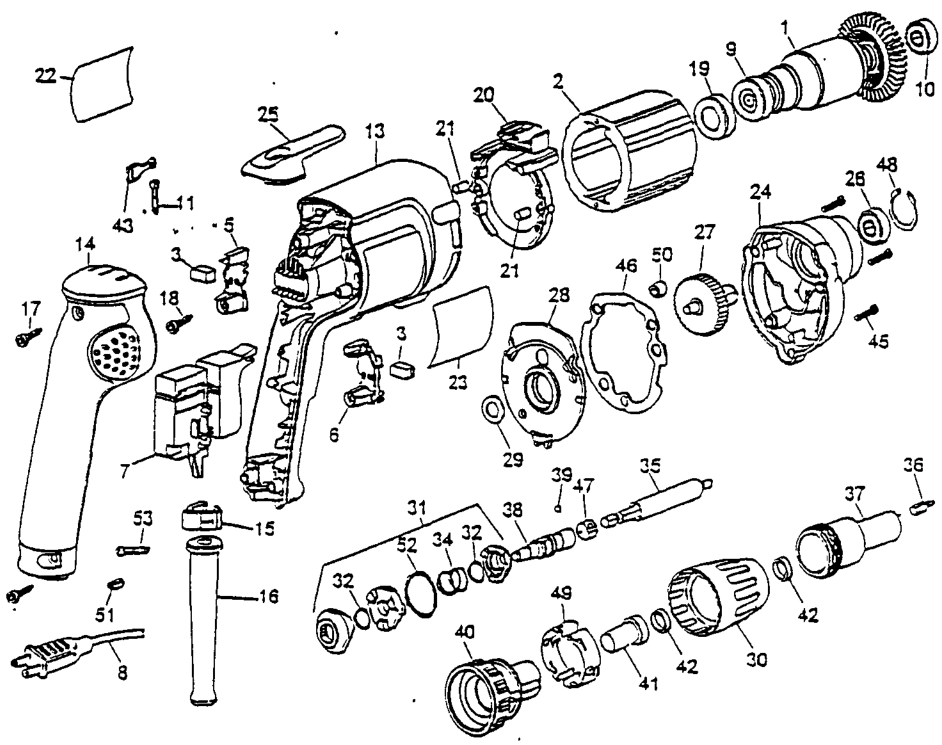


Figure 3 Major Components of a Drywall Screwgun [13]

During the semester, six engineers from the Black & Decker product development team presented a series of six lectures on the process of developing screwgun. These lectures covered the following topics:

Lecture 1: Introducing New Products to Market. It focuses on understanding the needs of end-users and the competitive screwgun market.

Lecture 2: Customer Surveys of the Product Attributes. It focuses on quality functional deployment to transfer the customer needs to product functionality and design specifications.

Lecture 3: Technical Challenges with the Product. It focuses on the design process to meet the product functional requirement, the method of design iterations and the use of the patent law to protect corporate inventions.

Lecture 4: Product Architecture. It focuses on the product realization process from the design phase to the manufacturing phase through the collaboration of departments within Black & Decker and the procedure to introduce new technologies into the product development.

Lecture 5: A Product Profit Model. It focuses on key factors which have significant influence on the new product development, the method of establishing a profit model, and the decision-making process to introduce new technology through trade-off analysis.

Lecture 6: Role of the Suppliers in Product Development. It focuses on utilization of the global network of supply chains to sustain the profit margin in the new product development and the corporate quality assurance procedure in the product development.

As illustrated in Fig. 2, the lectures presented by the instructor covered the following aspects:

(1) The organization of teams and training of team work.

(2) Trade-off analysis among the competing corporate objectives.

(3) Quality management and applications of engineering statistics on process control.

(4) Introduction to Pro/ENGINEER and rapid prototyping, an emerging technology in the new product development process.

During the entire semester, three projects were assigned to each student team. They are listed below:

(1) Performance evaluation of the new product of drywall screwgun made by Black & Decker. Two additional screwguns manufactured by two competitors in the market were also purchased. Each team was required to develop an evaluation plan to make comparisons among the three different screwguns in terms of function, efficiency, operational comfort, and pricing.

(2) Self-learning of manufacturing technologies. Six key manufacturing technologies related to the screwgun production were identified. They were injection molding, manufacturing of bearings, manufacturing of gears, manufacturing of clutches, rapid prototyping, and design for manufacturing and assembly. Each team was responsible for completing a detailed investigation of one of these manufacturing technologies and to present the results to their fellow students in class.

(3) Redesign of component(s) to improve product performance. Each team was required to submit a redesign proposal, present periodic team progress reports, and demonstrate the project completion by making prototype(s) of the proposed redesign. A final presentation by each team was made before an audience that included Black & Decker engineers. This redesign project represented a real challenge to the participating students. They had to identify a weak link in the product performance and apply their knowledge of design, manufacturing, and assembly so as to improve the product. To provide the participating students with the background knowledge for the project, a plant trip to the manufacturing plant was

arranged. At the manufacturing plant, the students examined the entire production line, stopped station by station, and talked to the operators to understand how components were manufactured and assembled.

The course evaluation is based on the individual student and team performance. The student performance evaluation consisted of bi-weekly homework assignments, paper-reading assignments, the mid-term examination and the final examination. The team performance evaluation included the project proposals, project presentations, and project progress and summary reports. Individual performance and team performance were weighed equally in assessing the students.

IV. Observations Made during the Teaching/Learning Process

In order to evaluate the teaching and learning performance, a survey from the participating students was conducted. Some of the student comments are selected to highlight the success of developing this new course..

(1) "The best part of the course was the Black & Decker lectures." All the students felt that they were better able to stay focused on the course objectives with a real product introduced to them. They understood the importance to meet the requirement of end-users, and what was needed in developing a new product. They gained a dynamic picture of the complexity involved in product development. Lectures presented by the six engineers from Black & Decker brought real engineering experiences to the classroom. The entire learning process turned to a unique training process to gain real-life experience. As a student wrote in the course evaluation, "I enjoyed having the break from class notes and the chance to listen to engineers who are out in the field." Figure 4 is a photo taken from the class at the time the students were working as teams to carry out the performance evaluation of screwgun.

Figure 4 Team Work on the Performance Evaluation of Screwgun

(2) "I understood trade-off analysis better because of the lecture on the profit model." Although an assignment of reading a technical paper to understand the competing objectives in developing new products was made, the students in class could not gain a deep understanding how to balance these competing objectives in real life applications. The methodology developed at Black & Decker to establish a profit model for decision making provided the students with a vivid picture of how to perform the trade-off analysis. By quantitatively defining the profit margin using the established profit model, and cost for alternating the existing production procedure, the investment for introducing new technologies are evaluated in direct comparison, instead of relying on experienced based qualitative judgments. It would be difficult, if not impossible, to present students with such vivid pictures taken from the real corporate practice. Figure 5 is a photo showing the interaction between the participating students and engineers from Black & Decker during a project evaluation. As a student wrote on the survey form, "Sitting down and

Figure 5 Discussion between a Student Team and Two Engineers from Black & Decker

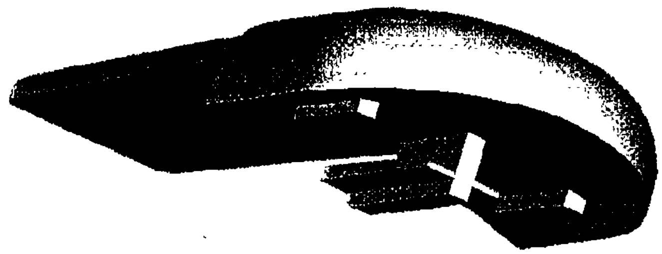
talking to the engineers about the project was intriguing. To hear first hand what an engineer thought of a redesign of his project was incredible."

(3) "Knowing how to work as a team was the best part of learning." The three assigned projects all covered a wide range of engineering aspects with depth. Completion of these projects required the students not only to share individual responsibilities, but also to work as teams. As an example, the project of investigating manufacturing technologies called for understanding material properties, equipment requirements, and process characteristics. The students had to go to libraries and the Internet to search for relevant information. They had to study together to gain a deep understanding of the subject. They had to practice

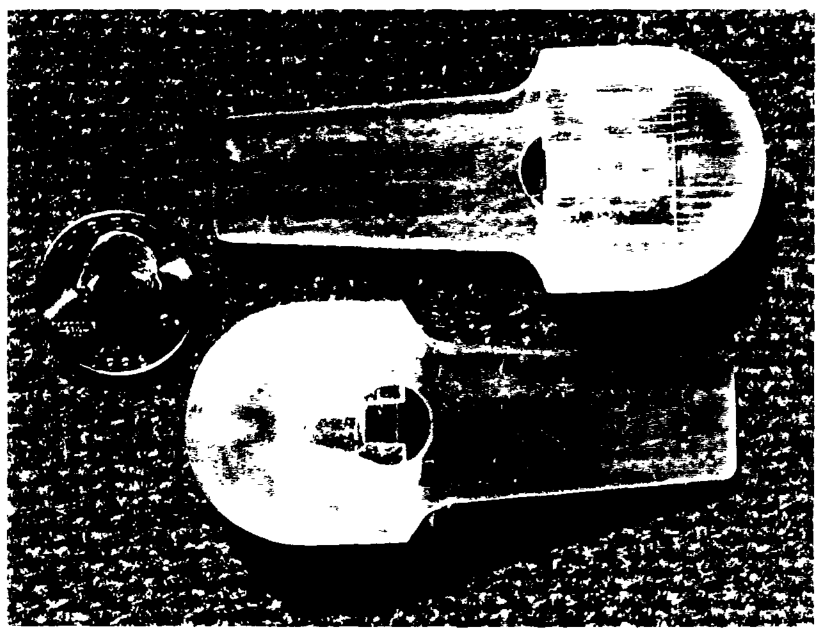
team work to prepare the project report and organize their presentations. From the Black & Decker's lecture series, the students understood that being exposed to team work is an important skill they need for tomorrow's engineering jobs. As a student commented on the team work, "My team worked really hard on the three course projects. These projects helped organize our team and let us become good friends. We gained a lot of knowledge through team work."

(4) "Learning Pro/ENGINEER and rapid prototyping to complete the redesign project was exciting." To equip the students to redesign a component or components, a computer-aided design package, Pro/ENGINEER, was introduced in the classroom. A special laboratory session in rapid prototyping was also arranged for them to learn the fundamentals and hands-on experience of a laser-based manufacturing technology. Figure 6a presents drawings of two redesigned clip structures to reduce their fracture rate and Figure 6b presents photos of the prototypes built using the stereolithography process. The successful realization of the redesign projects visualized the creativeness in the learning process and demonstrated the students' efforts through team work. As a student wrote in the course evaluation, "The best part of the class for me was to come up with new designs and to actually have the parts in my hand. I was literally thrilled by the whole process. I think I might have learned more in this class than in some other classes combined. Granted I did work incredibly hard, but in the end it was all worth it."

(5) "I enjoyed the instructor's lectures because they well prepared me for the Black & Decker's lectures." Recognizing the importance of providing the students with a comprehensive picture of the new product development, it is imperative for the instructor to organize his/her lectures which provide the fundamentals involved in



(a) A Redesigned Clips to Reduce the Fracture Rate



(b) A Built Prototype

Figure 6 Isometric Drawing of a Redesigned Clip and Photo of a Built Prototype

the new product development. The instructor needs to synchronize his/her teaching pace with the corporate lecture series. The material covered in the classroom teaching should meet the student's need to understand the contents delivered by the corporate engineers in the classroom. As commented by a student during the course evaluation, "In this class I never got tired of note taking because the classes were so varied. It was a good blend of topics to hold my attention." Therefore, the instructor's responsibility to ensure the learning efficiency can never be overemphasized under such a teaching environment because the classes were so varied. It was a good blend of topics to hold my attention." Therefore, the instructor's responsibility to ensure the learning efficiency can never be overemphasized under such a teaching environment collaborated with industrial partners. It is true that teaching this new course represents a real life challenge to the instructors. However, the learning experience is also truly rewarding to the course instructor.

V. Conclusions

This paper presents a new course developed at the University of Maryland to address the need for providing engineering students with both fundamental knowledge and real life experience in a new and successful product development process. Collaborative efforts have been successful with Black & Decker in a cooperative educational venture. The innovative teaching and learning is characterized by the following:

(1) A unique series of corporate lectures on the new product development to provide engineering students with an accurate view of how a new product is developed in the real world.

(2) The three course projects are challenging. However, they offer the participating students a terrific learning experience of gaining knowledge and skills of team work.

(3) Teaching leading edge technologies such as advanced CAD systems and rapid prototyping equips engineering students with skills which are of vital importance to engineering professionals and enhances their edge in the competitive job market of tomorrow.

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