Teaching Factory Approach to Engineering Management Education

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Abstract

An industrial partnership was established with a start-up company to plan and design a novel *pressure fresh* container for preserving fruits and vegetables. This was developed in a class project for a Manufacturing & Production Engineering graduate course. One self-directed team of engineering students generated a prototype design, manufacturing plan and cost estimate for producing the product.

I. Introduction

Loyola Marymount University (LMU) offers a part-time, evening M.S. degree in Engineering and Production Management (EAPM). It is tailored to working engineers with at least 3 years of industrial experience. Its purpose is to educate engineers in the manufacturing and management of competitive products for the global economy. The EAPM program integrates engineering and business into the curriculum and emphasizes developing products using concurrent engineering [1].

LMU has established a partnership with Eco Tech, a small start-up company, where the students have assisted the company in the planning and development of real products. It has been a win-win situation, because the students have gained valuable experience in implementing the product planning concepts in a classroom setting. In addition, the company has benefited from the students' assistance in developing new products. This is defined as the teaching factory approach, which has been successfully utilized with start-up companies in Japan and more recently in the United States [2].

Over the last 6 years, Eco Tech has performed research in preserving fruits and vegetables for up to 6 months without spoiling. The process has been patented under the name of *pressure fresh technology* [3]. This process was jointly researched with universities under a Phase I small business innovative research (SBIR) grant [4]. In order to prepare for a Phase II grant, a technology plan was required for commercializing the *pressure fresh technology*. The graduate engineering students assisted Eco Tech in creating this technology plan.

The paper will describe this class project for a 3 semester-hour EAPM course entitled, Manufacturing and Production Engineering. It was the first time the teaching factory approach was used in the EAPM program. This paper will discuss the project description, requirements and expectations, project organization, performance results, and the lessons learned.

II. Project Description

The project involved the design and planning of a *pressure fresh* home unit that would compete with Tupperware™ containers and refrigerators for preserving perishable foods. Interest had been expressed by the U.S. Navy, U.S. food processing industry, the Japanese, Chinese and Russians [5]. For the class project, the markets were assumed to be home units for the kitchen and recreational vehicles. The *pressure fresh* technology has been demonstrated in a research laboratory and verified on a farm [6]. The process utilized a container with a reverse seal, which was under a positive air pressure and at room temperature [3].

The goal of the project was to develop a technology plan and a business plan for producing pressurized containers with a reverse seal and pressure control. Due to **Eco Tech's** limited resources and partnership with LMU, a joint project was identified 'between the Colleges of Science & Engineering and Business Administration to assist the company. The engineering students would develop a technology plan, which consisted of a prototype design, materials and manufacturing processes, and cost estimate for building the home units. The business students would develop a business plan, which would consist of a marketing strategy and financial analysis.

The engineering students determined the customer requirements, design specifications, materials and processes, stress analysis, final design, manufacturing cost, and schedule to produce the **product**. The ownership of the product was to be controlled by **Eco Tech** with the understanding that LMU would receive a royalty if the product was profitable.

III. Requirements and Expectations

For the **project**, the students were required to submit a proposal, two team presentations and a final report. At the start of the project, the students presented a proposal to organize their work and schedule their tasks. The first team presentation was a preliminary design review that was conducted at mid-semester. The second team presentation and final report were due at the end of the semester and were conducted like a final project **review**. The class project was worth 40% of the student's grade in the course.

The students were expected to work as team to complete the project. Since the students worked full-time and were spread out over a 30 mile radius from campus, they were given class time to work on the project. Each week the students were given project assignments, and they were expected to hold regular meetings outside of class to work on the assignments as a team. A budget was not allocated for the **project**, because constructing a prototype was not required.

IV. Project Organization

The project was organized into one self-directed team of six students. The student team was **divided** into six managers according to the work breakdown structure of the project. Each student was a manager of one major activity and was held accountable for completing the technical tasks of that activity. The other students were expected to assist the **managers** in the completion of their activities. The six functional activities were: (1) customer needs and product specifications, (2) prototype design, (3) structural analysis, (4) materials selection, (5) manufacturing processes, and (6) cost estimation. At the completion of the project, the students combined their results and wrote a **final** report.

For the team meetings, the students were encouraged to organize themselves into 6 roles in order to distribute the responsibilities. The six roles were team captain, secretary, time keeper, featured speaker(s), evaluator and sergeant-at-arms. The duties for each position have previously been described [7]. These roles rotated for each meeting to give the students experience in conducting efficient meetings.

The team was supervised by a **project** manager, who was the instructor of the course. There were four technical **advisors** on the project: Global Business Incubator, Inc. (marketing agent for **Eco Tech**), President of **Eco Tech**, Director of EAPM Program, and the Associate Dean of Business Administration. The advisors were invited to the classes and project reviews. In addition, they were available for consultation during the semester.

V. Performance Results

The goal of the project was to design a *pressure fresh* home **unit**, develop a manufacturing plan, and estimate the cost for producing the units. The assumptions for the project were standard materials and processes, buying the components from suppliers, Food & Drug Association (FDA) approval on **all** materials and components, availability of replaceable parts (gasket seal, tubing and safety valve) and a hydrostatical y pressurized container. The concurrent engineering approach was used for integrating design and manufacturing

[8]. The activities **that** were utilized in the product planning and design process are shown in **Figure 1**. These activities were conducted simultaneously in the early stages of the planning cycle before the final design was determined. The results are briefly summarized below.

Figure 1. Product Planning and Design Process.

The students did not identify the market potential for the home units, because the market was unknown. Hence, the students referred to the product development as technology push, rather than market pull. Eco Tech had estimated the market size to be \$4B, based upon their research on a **competitive** product, i.e., **Tupperware™** [6]. Because the business students had not completed their business plan, the engineering students defined the customer needs by using themselves as customers. The customer needs were determined by brainstorming among the students and by consulting with the advisors. The list of customer needs consisted of ten prioritized factors: low cost, transparent container, chemical resistance, impact resistance, operational safety, compatibility with all fruits and vegetables, removable container lid, use on kitchen shelves, pressure indicated by sensors, and lightweight.

The target specifications were determined for the size of the container, container pressure, rubber seal, durability (10 years), aesthetics (color and shape), and maintenance (30 years for replacement parts). The container material was selected by concept scoring [9] to be **pol**ycarbonate (**Lexan 144**). The customer needs and specifications were translated into the preliminary design using quality function deployment [10]. A **Taguchi** parameter design [11] was conducted before the preliminary design was developed. The parameters could not be optimized, because a prototype was not constructed and tested. The preliminary design was generated on Auto CAD and modified for the final design.

The container structure was analyzed for the stresses and wall deflection under 41.3 **kPa** (6 psi) pressure. The minimum wall thickness was selected for a safety factor of 2 over the ultimate material strength and for ≤ 0.025 mm (s0.001 in.) expansion of the container walls. The structural analysis was performed using thick

wall equations for the wall faces and corners [12]. The calculations produced a wall size of 6.4 mm (0.25 in.) that was considered to be both safe and lightweight.

Blow molding was selected as the process for fabricating the container. Process flow charts were used to define the processing and assembly of the container (vessel, lid and handle, seal, valves {intake, exhaust and safety}), pressure control system (power supply, programmable logic controller, pressure transducer), base, and compressor system (compressor, air filter and water container).

Network diagrams were created to identify the processing and assembly activities, and their times and costs for each activity. The critical path was determined, and Gantt charts were constructed. The process times and number of units built per hour were estimated [13]. These were not optimized for smallest number of parts. The cost of materials and labor to manufacture the *pressure fresh* units was estimated to be \$400 per unit.

VI. Lessons Learned

For interaction with industry-sponsored projects, it is important to have a written agreement upfront on how to handle intellectual property, ownership of innovative concepts, licensing and potential royalties. At the **start**, the students were upset, because they felt the project was forced upon them. They did not “buy into” it immediately, and too much time was wasted in organizing their activities.

Although the scope of project was considered realistic for a **graduate** course, it was too complicated for a one semester course. The *pressure fresh* units it had too many parts and manufacturing processes. In the future, a simpler product should be selected, i.e., one with less than 10 parts.

The greatest problem was the limited contact time that the students had to work in teams. Since the students were spread out all over Los Angeles county and had demanding full-time jobs, it was difficult for them to hold team meetings outside of class. The students used e-mail, FAX and phone **calls** to correspond with each other. Hence, the students were given 1-2 hours per week of class time to work on their project. This caused the project to take over the class. Nevertheless, it forced the students to come to class prepared for their team assignments.

The students were evaluated **based** on the results of the team. A problem arose where the individual contributions were not the same for all of the students. Some students worked harder than others, and there was some animosity created between the students. Each student was asked to anonymously grade the performance of the other team members. To our **surprise**, all of the students graded their team members “high,” which did not reflect dissatisfaction in the work habits of their team members. In the future, the individual contributions will be documented by each **student**, and these will be confirmed by the team captains.

The engineering students did not work concurrently with the business students, because the project overlapped two semesters and was **incorporated** into two **different** courses. The project needed to have the business students perform the marketing research and to interact with the engineering students in a **multi-disciplinary** team.

These lessons learned will be integrated into a new course. The course will be taught by cross-functional faculty and will include multi-disciplinary teams of engineering, business and industrial design students. The students will work together in teams to design and build a prototype products. A budget will be provided for each team to build an alpha prototype of their product [9].

VII. Conclusions

A class project in a graduate engineering course was identified to assist a small start-up **company** in developing a design, manufacturing plan, and cost estimate for producing *pressure fresh* home units, which

would preserve fruits and vegetables for 6 months. The market size for these units in homes and recreational vehicles was estimated at \$4B.

The project had one self-directed team of six engineering students and was organized into six functional activities: customer needs and product specifications, prototype design, structural analysis, materials selection, manufacturing processes, and cost estimation. Quality function deployment was used to **translate** the customer needs and specifications into the design. Based on these results, a new course **will** be designed, which will **incorporate** both **multi-disciplinary** faculty and student teams.

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