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RealTimePC: Case Studies of the Roles of an Industrial Engineer

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Abstract

Convinced that everyone should develop Industrial Engineering (IE) skills, IDDEAS, an interdisciplinary research group of engineering students collaborate with the Real Time Process Control (RealTimePC) Outreach Initiatives every year. With empirical studies reporting that teenagers are more likely to pursue an engineering career when they have knowledge about what engineers do, RealTimePC's objective is to inspire and engage young students in pursuing a career in IE. For students to experience the different roles an Industrial Engineer can partake inside a business, all RealTimePC initiatives cover the IE roles defined as: Project Management, Quality Measurement & Improvement, Supply Chain Management, Production, Distribution & Logistics, Human Factors & Ergonomics, Financial Engineering, Strategic Planning, and Manufacturing Processes Engineering. To enhance experiential learning, the RealTimePC team has developed case studies for students to practice and reflect about each role. When possible, the case studies are also designed to have a relationship with Process Automation. Considering the limited number of IE case studies available in the literature and RealTimePC's experience of five years, this paper shares these results for the benefit of other outreach programs around the world.

Keywords
Outreach, Industrial Engineering, Experiential Learning

1. Introduction

Many universities have adopted outreach programs as a means to promote engineering to the community and, especially to get high school students interested in the career. To achieve this, college professors and students develop summer camps, weekend activities and high school workshops, among others. Most outreach initiatives concerning Industrial Engineering (IE) are topic specific. Some only focus on an Industrial Engineer's role in an assembly line, healthcare systems, or implementing specific tools such as simulation and facility layout, etc. [1, 2]. Although these types of topic-specific activities teach about optimization and efficiency, which are key elements of IE, they lack to provide a comprehensive understanding of the career. With the common problem of being misunderstood, a holistic appreciation is necessary for the community to comprehend the abstract concepts that make IE an important opportunity to improve all types of systems while offering a broad career for generations to come.

A survey, conducted by Intel Corp., indicates that teenagers are more likely to pursue an engineering career when they have knowledge about what engineers do [3]. With this in mind, RealTimePC leads activities to promote IE by dissecting the profession and teaching about every role an IE may have in the work field [4]. Based on the definition of the Institute of Industrial and Systems Engineers (IISE) of the IE career and an analysis of commonly used terms and acronyms, the RealTimePC team defined the IE roles to include: Project Management (PM); Production, Distribution and Logistics (PDL); Manufacturing and Process Engineering (M&PE); Supply Chain Management (SCM); Ergonomics and Human Factors (EHF); Strategic Planning (SP) and Financial Engineering (FE) [5]. With this in mind, case studies were developed for students to experience and reflect about the different roles an IE can perform through hands-on activities, poster designs and peer-to-peer presentations. The different IE roles are reinforced in other summer camp activities, for example at the IE Olympics, factory tour and closing event.

2. Case Studies of Industrial Engineering Roles

IE is a very broad, and therefore complex, career. Following IISE's description of the IE career into eleven focus areas, Industrial Engineers work to improve processes, products or systems with roles related to: (1) Manufacturing, Production and Distribution, (2) Supply Chain Management (3) Productivity Methods and Process Engineering, (4) Quality Measurement and Improvement, (5) Program Management, (6) Ergonomics/Human Factors, (7) Technology Development and Transfer, (8) Strategic Planning, (9) Management of Change, (10) Financial Engineering, and (11) Project Management [4]. The RealTimePC team summarized these eleven categories in eight (Figure 1) using common terminology and acronyms while adding pictures that help promote the IE roles throughout the whole RealTimePC experience. Case studies were developed for students to apply these roles using experiential learning and peer-to-peer learning approaches. These strategies provide students their own space to develop their best understanding of the topics. The case studies were also related to process automation, when possible, giving students the opportunity to see how the two combined on the problems that they could manage as IEs.

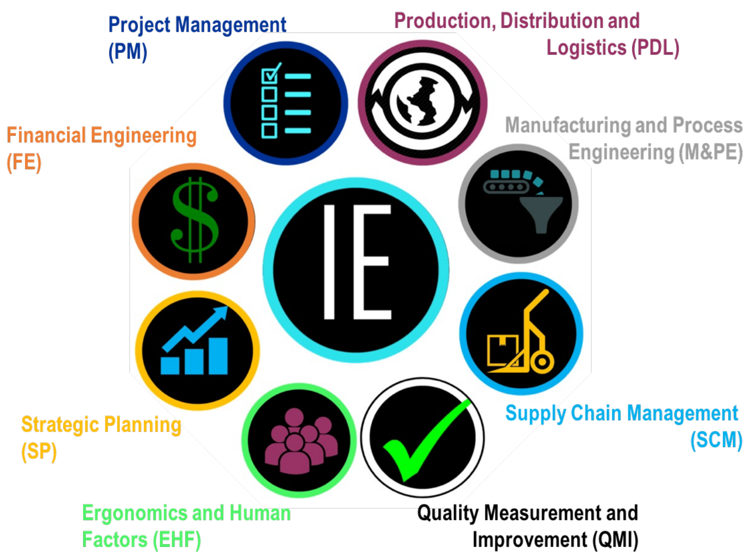


Figure 1: Industrial Engineering Roles

Peer learning is implemented after the students complete the case studies based on the IE roles. Reis [6] supports peer learning stating that "students learn a great deal by explaining their ideas to others and by participating in activities in which they can learn from their peers". RealTimePC includes peer learning by having students prepare posters of the role they experienced and presenting their role to their peers in the form of a creative presentation that may include some dramatization. Meanwhile, the poster preparation serves as a team reflection of what they have learned in the case studies and how they would like to present it to their peers. The following sections describe the different case studies the RealTimePC team has developed.

2.1 Project Management (PM)

Project Management is defined as the application of knowledge, skills, tools, and techniques to project activities to meet the projects requirements [7]. For the PM role commonly used tools such as the Precedence Diagram, the Critical Path Method (CPM) and the Gantt chart were used to show students how planning is performed in any project. The precedence diagram, as shown in Figure 2, consists of nodes and arcs that represent the project activities and their dependencies. The activity included explaining the diagrams with a simple example so students could have an idea of how the diagram is created. Then, students were exposed to a case study where a list of activities in no particular order and time of duration was given. Students had to figure out the dependencies and create the precedence diagram for tasks related to process automation. After this, they had to find the critical path to determine the duration of the project using CPM. A Gantt Chart, like the one shown in Table 1, was given for students to learn about the monitoring and control part of PM in which students had to reflect about potential reasons for the project delay while providing recommendations to finish the project on time and with minimum cost adjustments. This activity provides an excellent overview of PM and the steps required to automate a process with the use of simple and commonly used tools.

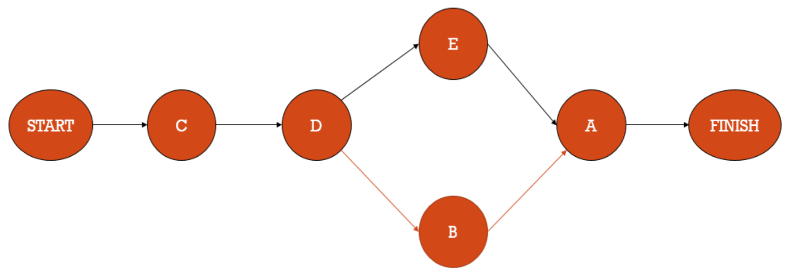
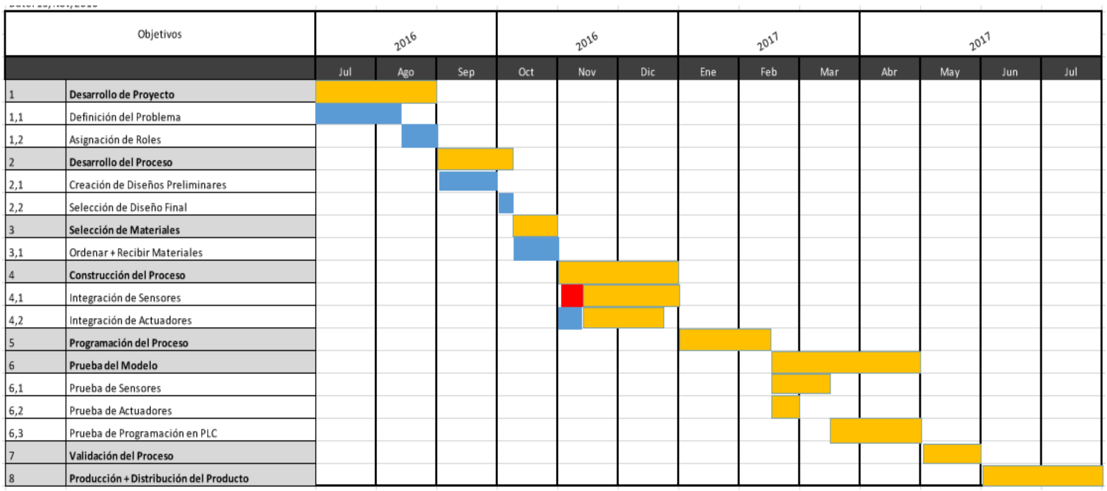


Figure 2: Precedence Diagram

Table 1: Gantt chart



2.2 Production, Distribution and Logistics (PDL)

In an attempt to remain competitive and improve their operational performance, companies are constantly trying to search for new optimization models, computerized tools and algorithms to enhance their analysis of production and distribution operations [8]. That is why the RealTimePC team developed a case study for students to learn about production, distribution and logistics. The activity stars with an explanation of the three basic concepts. Once the concepts were understood, the students were presented with a production-planning problem defined in the context of a chocolate factory. Data of the demand, lot size, packaging, work shifts and production capacity were provided for the students to analyze. Along with this information they were provided template as shown in Figure 3. At the end of the activity, students were expected to understand the importance of planning and the use of resources in a production line.

In the second part of the case study, students were assigned to find the optimal route to distribute the products. They were given the information of the distribution centers of the company and the towns that required distribution. It was also emphasized that the product was perishable and it could not be stored for more than one month. Students were provided with a transportation cost per mile and an overall cost of transportation from the factory to the distribution centers. In order to know the exact number of miles from one town to another, they were provided with a computerized tool from the Puerto Rico Government Department of Transportation and Public Works website that calculates miles between towns. They were also provided with the template shown in Table 2 in order to design a route. The objective is for students to understand that distribution is one of the most important steps despite being one of the last steps in the logistics process. Integrity and quality of the product must be ensured and the clients must receive the product when expected.

Weekly Production Plan															
Daily Production Capacity:							**Weekly Porduction Demand:** 300 choclates per week of each								
Milk Chocolate: 150 chocolatesper day															
Almonds: 10 chocolates per day															
Cookies and Cream: 75 chocolates per day															
	Monday			**Tuesday**			**Wednesday**			**Thursday**			**Friday**		
Recepies	Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3	Shift 1	Shift 2	Shift 3
Milk Chocolates															
Almonds															
Cookies and Cream															

Figure 3: Template for the production plan

Table 2: Example of template for the most optimal route.

Towns	Miles	Cost per mile	Cost
Mayagüez to Cabo Rojo	9 miles	0.75	$6.75
Cabo Rojo to Yauco	23 miles	0.75	$17.25
Yauco to Isabela	58 miles	0.75	$43.50
Isabela to Mayagüez	30 miles	0.75	$22.50
		Total	**$90.00**

2.3 Supply Chain Management (SCM)

This case study aims to ensure that students understand the concepts and principles of SCM. Students were assigned a product and they had to develop the bill of materials (BOM) by identifying the components and materials of their product. Once they created the BOM, the students proceeded to create a diagram of the supply chain, from the raw materials to the distribution. Following, the students had to identify suppliers for the components of their product and evaluated them to choose the best supplier. Students evaluated each supplier based on 4 factors: cost, quality, time and trust. Students discussed in a group the factors that were of greater importance for them. Once the students finished their discussion, they had to rank the factors to show their relevance in the decision. With this ranking the students were able to calculate the weight for each decision criteria. The calculation is simple and it based on the Borda Count Method, this method is designed to choose the best candidate from a list of alternatives, placing the candidates in order of preference, assigning points for each candidate or alternative [9]. The process continues with assessing the different alternatives in terms of the criteria and their weights. In this process normalization of the values was important to assure that all the values are on the same scale. With this case study student do not only experience SCM but also learn about multiple criteria decision-making and Microsoft Excel.

2.4 Quality Measurement and Improvement (QMI)

QMI is the set of managerial, operational, and engineering activities that are used to guarantee that the quality characteristics of a product are at the required levels and that the variability around these anticipated levels is minimum. Industrial engineers are the ideal candidates to work with the QMI since they interact with both management and the workers [10]. Therefore, RealTimePC created an activity that ensures students learn about QMI. The activity consisted of observing several runs of an automated process and documenting the number of products that fail as a result of not complying with the quality criteria. With these observations students calculated the probability of failure (Equation 1) to comply and, with this, calculated the probability to find the defective product (Equation 2) in the first, second and third inspection. Then they had to calculate the probability of finding a defective product in or before the second try and then the third try. Finally, the analysis was made and students had to evaluate the capacity of detecting changes in the process and made improvement recommendations. Through this activity students also learn about analytics and statistics, which are both key elements of IE.

$$f(x) = p^x \cdot (1-p)^{x-1} \qquad (1)$$

$$F(x) = \sum_{1}^{x} f(x) \tag{2}$$

2.5 Ergonomics and Human Factors (EHF)

Ergonomics is the discipline or science responsible for designing workstations, tools and tasks that allow the efficient and healthy interaction between the worker and the workstation. On the other hand, there are human factors, which studies the interaction between machine and operator. Ergonomics reduces fatigue while human factors reduced error. Visual representation help students remember easily the different risk factors related to ergonomics. For learning purposes, an animation was used. Students observed carefully two scenarios for various activities. One scenario showed the activity done without the application of ergonomics, and the effects this had on the workers, causing trauma. The other scenario, showed another worker, doing the same activity, but applying ergonomics, and staying physically healthy. Later, students were given a case study to analyze how different designs of process automation were appropriate for the material handler to move materials and/or technicians to repair the machines. For example, the tasks completed by the material handler (simulated with toys) included carrying heavy boxes from the warehouse to the input side of the assembly line. The line was low positioned, and the operator had to bend more than 45 degrees. Also, when the technician was troubleshooting the line, it required working in extreme postures. To decide on the need to re-design the workstations students implemented the work sampling technique to determine the frequency in which the tasks were done. Following, they suggested alternatives to lower the risks for the worker.

2.6 Strategic Planning (SP) and Financial Engineering (FE)

The success, reliability and continuous improvement of a project depend on its organization. This is where IEs apply strategic planning methods to foresee possible outcomes and make the best possible decision. An important aspect in decision-making is considering the financial factors. The best solution to a situation could be the most profitable solution. Therefore, Financial Engineering was presented together with Strategic Engineering given their strong relationship in decision-making. Implementing both roles together, students were provided with a backstory of a fictional company. The example of the exercise is as follows: If the company Pizza To' Go sells 10,000 units of pizza yearly with an employee that walks an average of 20 steps to produce each unit, the marginal cost of producing a pizza is $6.13. This company wants to increase production to 40,000 units of pizza and also intends to reduce costs within a one year period." In order to achieve its goal, they will have to invest in automating their production line. With the increase in production fixed costs will stay the same, but the variable costs of each unit decrease due to wholesale prices. Assuming the variable costs decrease by 7% the new marginal cost of producing a pizza is of $5.31. Some fixed costs might vary, like reducing direct employees but they are later needed as machinery maintenance employees, therefore, the fixed costs are assumed the same. With the new marginal costs, students calculated the percent of change in costs, which is attractive to customers. This increase in production had other implications such as a decrease in the sales price with the same profit ratio and an increase in net revenue. With the annual profits calculated and assuming an inversion of $53,000 the investment would be recovered after 6 months.

3. Program Assessment and Conclusions

RealTimePC differentiates from other programs by provided a holistic experience that allows understanding the IE career as a whole while also learning about process automation. To assess the effectiveness of the RealTimePC program pre and post camp surveys were implemented. For example, Figure 4 shows how the students consistently increased their knowledge in the three areas presented. In addition to learning the IE roles, as per discussed in the literature [6], through this activity students develop confidence, as well as organization, teamwork, planning, and creativity skills. In addition to the case studies, RealTimePC also reinforced IE through different activities. For example, all the roles are included in the IE Olympics that consists of a scavenger hunt around the campus. Students were divided into groups and are provided with clues and an exercise related to the IE roles. Completing the exercise along with analyzing the clue helps them proceed to the next place. At the end, the group that returns to the starting point fastest looking into the shortest route wins the competition. The IE roles are reinforced in an enjoyable way. A plant tour is also used to reinforce what students learned in which they can observe and ask questions about the application of the roles in a real setting. Figure 5 summarizes how students were satisfied with the different activities showing values over 80% for all of them. Finally, the IE roles are included in the closing event in which the Kahoot website is used to quiz participants and their family members about the meaning of the IE roles pictures and acronyms. To conclude, reinforcing the IE Roles through experiential learning and peer-learning techniques has shown excellent results in the RealTimePC program. It has given students the opportunity to remember each role with more ease and increase skills of organization, teamwork, and auto evaluation while also learning about optimization and efficiency, fundamental characteristics of an Industrial Engineer. The benefits are not only observed in the program participants, but also in the engineering undergraduate students leading the activities.

Figure 4: Knowledge of Areas of Specialty

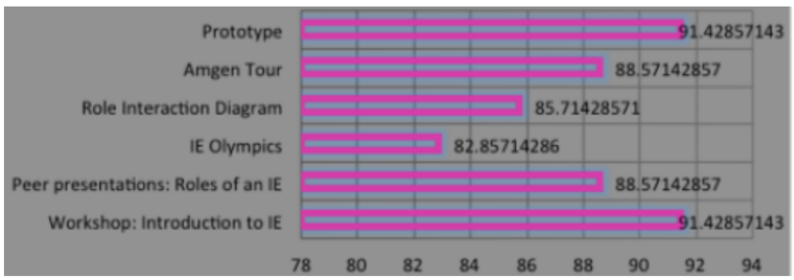


Figure 5: Student satisfaction learning about IE throughout camp activities

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