The Plant Layout Project Revisited

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The plant layout project has been the mainstay of industrial engineering curriculum for many years. Yet, even today, some schools miss the educational opportunities offered by these projects. While working through the steps of the layout design process, students can be exposed to exercises in open ended problem solving, business communications, computer modeling and team participation. All of these facets of the process occur naturally. However, unless proper design of the project and its evaluation mechanisms are considered, the full benefits of the assignments will not be realized.

This paper presents the plant layout project as a tool for experimental learning on a broader front - from communications through engineering design. Opportunities for exercises of various kinds are explored. Throughout the paper, the Virginia Tech layout project is discussed to provide a contextual framework for the presentation.

Introduction

Today, more than ever before, there are many efforts within universities to enhance the curriculum and to provide a more meaningful and relevant educational experience for the students. Often the motivating forces for these changes are coming from outside the academic environment - from the industrial sector, from state and national government, or from the students and their families. However, these changes are also being brought about by the desire of the faculty to enhance the education process -to refine “the system” so that the service that is provided is one of continuous improvement. Much of these efforts call for drastic changes in the educational process. Others are simple changes that can have substantial paybacks. This paper explores one such change - an enhancement of the projects often given in a plant layout course.

There is a need for a capstone design experience in engineering education. This experience should encompass two basic ideas. Firstly, the capstone course must encompass engineering design - the problem or problems addressed in the exercises should be open ended. There should not be a “text book solution.” Rather, the students should explore alternative solutions and alternative analysis techniques in arriving at the answer. The problems should contain both quantitative and qualitative factors - it should have areas where trade-offs must be made with respect to conflicting objectives. The process to be used in obtaining the answer is as important as the answer itself Secondly, the capstone experience should combine or integrate ideas and concepts learned in different courses. Economic analysis concepts can be combined in simulation study to provide information for decision making. Probabilistic data can be used as input to a deterministic optimization process through the use of averaging. A capstone design experience does not stand alone - it must serve as the integration agent for the discipline specific curriculum. For many years, this has been recognized as an important process in the education of industrial engineers. More recently, however, it is getting attention. in many other areas of engineering education[2,3]. Various engineering disciplines are implementing design projects in a variety of courses and formats in the final year of the program.

In a report issued by the National Research Council[4], three basic ideas are presented with respect to engineering design education for the undergraduates. First, undergraduate engineering design should show the relevance of fundamental materials introduced in other courses. As such, engineering design becomes the agent of integration. Next, it should teach the students what the design process entails - what are the basic steps involved, what is the role of synthesis and analysis in the design process? Finally, design is not just providing functionality. It includes probability and statistics, economic analysis and optimization. But design need not be limited to the final year of the undergraduate program. Concepts in the engineering design process can be taught at all levels of the engineering curriculum. There are design oriented courses used to introduce first year students to engineering fundamentals. Design concepts can be taught to sophomores or juniors[6]. And of course, design courses are appropriate for senior level courses and a capstone experience. But is it possible to offer a capstone experience before the senior year? Can much of the value of a capstone experience be gained by a junior who has completed the vast majority of the required undergraduate curriculum? This paper presents such an idea.

There is one final note that needs to be addressed before getting to the basics of the paper. An industrial survey by Shunk and Wolfe[5], indicates that three things are needed for the graduates to become world class manufacturing professionals. First, there is a need for the development of better communication skills that specifically relate to the everyday tasks of the practicing engineer. Next, less dependency on a piece of software must be established. The student must give up the idea of “the equation,” “the optimization package,” or “the computer routine.” Rather the student must learn to improvise or modify equations and concepts as appropriate to the situation at hand. Finally, the student must learn the ability to solve an unstructured problem. Much of the thinking in the paper is based upon these ideas.

Beliefs

There are five basic beliefs that have governed the design and development of the plant layout project presented in this paper. 1) Design is not just for seniors. It is important that design concepts be integrated at various levels of the academic program. Key courses can be identified wherein design can be introduced in a natural setting - plant layout is one such course irrespective of the level of the offering. 2) The capstone experience can be enhanced if it is first introduced at a lower level course via a limited “test run” and then fully realized at the senior level. Our plant layout course provides the opportunity for such an introduction. Students should be exposed to real world situations and issues within a context or framework that models the types of situations that they are likely to encounter as practicing engineers. 4) Basic communication skills need to be exercised within the framework of the engineering experience. 5) Computer usage should not be limited to computer classes but should be integrated into other class exercises with relevant applications.

Of equal importance to the above, is the belief that education is an interactive process conducted in partnership with the students, rather than a one-sided activity done to the students. Students must be involved in the learning experience through exploration and discovery. Faculty must be willing to commit the time and energy necessary for guidance, evaluation, and feedback. Projects cannot be viewed as class exercises or tests of knowledge. Concepts presented in a lecture setting need to be applied in a realistic situation to fully reveal the strengths and weaknesses of the models and their assumptions. A design project is a learning experience and it must be approached with this in mind. Such an exercise will require substantial commitments from both the faculty and the students to fully realize the impact of the process.

The Curriculum . .

The undergraduate ISE curriculum has recently undergone some modifications which make the present situation ideal for the changes that have been introduced into the plant layout project. ISE 4214- Facilities Planning and Materials Handling was moved from the last semester of the senior year to the last semester of the junior year and was renumbered accordingly to ISE 3214. In this new position, the course still has as prerequisites 1) a year of operations research (both deterministic and probabilistic modeling), 2) a basic course in manufacturing processes, and 3) courses in methods engineering and human factors engineering. Additionally computer simulation is a co-requisite to the course. As such, the students will have had or are taking most of the required undergraduate ISE classes except for production planning and control and quality control which are taken in the first semester of the senior year. Most of the fundamental courses are in place.

Of equal importance is the fact that ISE 3214 is now a prerequisite for the two senior level capstone courses. The experience gained from participation in a plant layout project can be used as input to the senior design courses where students will actually participate in teams working on a real industrial problem. As such,. the plant layout project can serve as a model for the "how to" of the engineering design process and this must be of concern in the design and evaluation of the projects.

The Course

ISE 3214 Facilities Planning and Material Handling is a one semester, three credit course that has three scheduled, fifty minute lectures each week. The grading policy includes 25% for a midterm examination 35% for the final examination, 15°/0 for homework assignments, and 25% for the term project. The course for the text is ***Facilities Planning,*** by Tompkins and White[7]. One faculty member is assigned to the lecture portion of the course (two sections with a total of about 85 students) while another professor is in charge of the project. There are two graduate teaching assistants assigned to the course who perform grading tasks associated with homework and assist in gathering materials for the project assignment. All grading and interaction associated with the project is handled by the faculty.

The Project

The basic goal of the project assignments is to provide a practice oriented experience to improve the understanding of the concepts involved in the design of a manufacturing facility. This has not changed over the years. Concepts presented in the text are identified and imbedded in the project assignments to guide the students through the layout design process. The project attempts to expose the students to real issues in the process in an unstructured manner within a realist framework of reference.

What is new in the recent project assignments, however, is the desire to provide an integrated learning experience where materials from prior courses come together to focus on a real problem environment. Additionally more emphasis in the project is being placed on business communication skills assessment and computer applications evaluation. These changes effect both the design of the project and its evaluation process.

The initial handout for the project includes a detailed description of a hypothetical company that is seeking to expand its production facilities. The 20 page document includes information on past sales and sales forecasts, basic product information on each product line that addresses issues in options and variability, and manufacturing process data including production sequences and standard setup and operation . times for each product. Also embedded in the document are statements regarding trends in the market place as perceived by the management of the company. Additional information is added as needed, but the initial document is somewhat overwhelming to the students at first glance.

Three specific assignments are given to the students that subdivide the plant layout process into more manageable pieces. The initial project assignment addresses the formulation of the design specifications. What are we trying to make? What quantities are required? What processes are involved? And what quantities of equipment are needed? At the end of this phase of the project, the students have identified the production requirements of the proposed facility. The second assignment centers on space requirements and the interrelationships between the various areas of the proposed facility. This includes product, storage and support functions. Since the facilities being addressed are fairly small, administrative functions are kept to a minimum. The last requirement of this assignment is for each team member to propose an alternative layout. The final phase of the project focuses on the evaluation of the alternative layouts and a design of the material handling system. Once each layout alternative is evaluated, a final layout is selected and appropriately documented for the final report.

Project Teams

Individuals join a project team based on personal preferences. It is suggested that teams consist of four individuals who are not part of any ongoing project work. This is done to limit conflicts in objectives as teams meet to work on the layout project. Teams with three members are permitted, however no team is permitted to have 5 members. Team formation by the faculty has been considered, but this policy has not been adopted due to concerns expressed by the students.

Some Project Details

The project this year focused on the design of a new facility for a small company that produces products to support the personal computer market. The company has three major product lines - cables, boards and electronic boxes. Each of these product lines is subdivided into three or four sub-product lines. While it is assumed that the students have a general knowledge of the products associated with the company, they do not have a background in the processes involved in the new facility. This choice was made to provide a fairly even playing field for all students involved. Many of the problems and issues which are addressed in the project are related to the design of the facility. But often specific questions and assignments are added to force the students to integrate knowledge gained in other courses.

For example, students are accustomed to being given data which is then plugged into equations to produce answers. In the information provided to the student, much of the data is probabilistic in nature. Some of the data is given in percentages while other data is specified as a range of values. The students must decide what data to treat probabilistically and what approximations must be made when it is desired to have a single, representative value to use in a calculation. Additionally, one or two pieces of data are actually inconsistent - the statement in the sales and forecasts section of the information package regarding a few of the processing times actually differs from the values given on the process specification sheets. A situation not uncommon in an actual situation. Students are often faced with the fact that "the textbook equation" is not fully applicable the situation being described.

One important aspect of the problem statement is that the students are not told what production level is to be used for designing the new facility. They are given historical data including seasonal trends and annual sales forecasts for 1, 2, 5 and 10 years into the future. Some of the sub-product lines are expected to . have dramatic increases over the next few years while others are actually forecasted to have declining sales. There is no right answer as to what production volumes should be used. Rather the emphasis is on how the students go about deciding what data is important. Are the seasonal trends important? What quantitative statements can be made to support that decision? Given the specified forecasts, when will the proposed facility be inadequate and need to be expanded? Given the massive amounts of data involved in the problem statements, it is suggested that students setup spreadsheets and "play" with the numbers until they are comfortable with their decisions. This advice is not understood by many of the teams which simply settle on a given year without an adequate realization of the consequences of that decision.

Another problem area that is proposed early on in the project is a make / buy decision. The company presently purchases the plastic and metal boxes from an outside source. Management is considering bringing that production in-house. The students are asked to evaluate that decision based on their knowledge of the various manufacturing processes involved. Immediately they want to know how much the equipment costs. They are told to plan a processing sequence for each of the box types and provide some reasonable estimates for the cycle times. The emphasis in this part of the project is on how that information alone might be able to provide input into this decision. Equipment utilization can be used to justify this decision in a non critical aspect of the manufacturing process technology.

Later in the course, students are faced with an equipment selection problem. The list of available suppliers is limited to a single vendor who has provided data on five possible alternatives. Purchasing information as well as operating data has been supplied. Because of the nature of the probabilistic data, students will have to combine a simulation study with a cost model to arrive at a reasonable decision. The students are actually required to develop the simulation model to study the effects of variability on production sequences, but the model can also be used in the equipment selection problem.

Knowledge gained from the methods engineering class will come into play in two separate areas. First an understanding of time standards is necessary to sort through the data provided on process times and machine requirements. Students must realize what kind of allowances are integrated into the "standard time" established by a methods engineering study before applying the adjustment factors suggested in the layout text. Additionally, the students are asked to design an individual workstation in order to establish a space requirements standard for that operation. Data on other processing stations is provided where needed.

Support areas and storage space requirements must be estimated by the students. Guidelines are provided, but the students are free to make a number of decisions in these area. Some designs will have four to five times the storage space as others. The emphasis is on how the design is justified. Additionally, the teams must examine the relationships between the various areas from both a quantitative and a qualitative perspective. It is interesting to see how little emphasis many of the undergraduate engineers place on qualitative data.

Communications

The project emphasizes both oral and written communication skills. Each of the three assignments requires a written report. Thirty percent of the grade on the first report is associated with the organization, content and style of the body of the report. Students quickly learn that raw data and pretty pictures do not constitute a formal report. A formal letter of transmittal is required after the first report.

The final report must be accompanied by a layout drawing using standard layout practices. The students are required to use either AutoCAD or CADKEY in preparing their drawings as these two software packages are supported in the laboratory facilities with the plotters. Buildings and rooms must be drawn with walls that have thickness and are not represented by a single line. Templates of the workstations must be used so that the positioning of the various pieces of equipment can be visualized. An appropriate scale must be chosen that is representative of an engineering standard used in layout presentations. For many students, this is really the first time they have to exercise the knowledge they gained in the engineering fundamentals classes.

Finally, each group is required to make a presentation of their final layout. The presentations are then video taped and the student must review and critique their own presentations. Because of the significant amount of time involved in this part of the exercise, students are only required to attend a very limited set of presentations of other groups.

Computer Experience

Cedarleaf commented that the layout process can be done with a calculator and a drawing board - however the capabilities offered by the personal computer make the old way of creating a layout obsolete[1]. It is in this spirit that use of the computer is emphasized in the assignments. All documents are expected to be word processed and presented in a professional manner. Definitely, dot matrix printing is acceptable, but the quality of the text behind the printed character is of interest. The modem word processor can greatly assist the individual is getting across an idea. Students are encouraged to use graphs, charts and figures to illustrate their points. As stated earlier, the use of spreadsheets is almost a necessity. The amount of calculations and data reduction required prohibits hand calculations. Again these packages can be used to make illustrations that support an argument. The final layout must be produced on a CAD package and plotted in the laboratory.

The only real "computer" assignment is the simulation study in the last phase of the project. Students are asked to develop a simulation model of the flows within the production facility to analyze the effects of variability on equipment availability and utilization. This exercise was partly developed to show how important variability can be in a capacity study. Earlier in the project, probabilistic data sets were often collapsed into an "average" value which was then used in some calculation to determine a needed parameter. The simulation study illustrates that the variance of the data maybe as important as the mean in some instances where serial production systems are involved with limited buffer storage. Additionally, the simulation study can be used in the equipment selection study discussed earlier.

A new aspect of the project that was added this year is the use of the Internet for specific components of the project. First a list server account was established and then used as the formal means of communications between the project teams and the project instructor. If a project team had a question that needed to be answered, they could post the question to the list server. The course instructor monitored the list server and sent a reply by posting it to the list. In this fashion, all questions and answers were seen by the entire class. An important observation about this process was that student initially had problems expressing their questions in a written form. In the past, a student could "drop by the office" and sort of "feel" his or her way through the problem with some guidance from the instructor. Under the new system, questions had to be formalized and presented in a manner that all could see. This specific aspect of the course required a substantial amount of faculty time to provide timely responses to the questions.

-additionally, one assignment required the use of the World Wide Web to locate alternative suppliers . for the material handling equipment. Students were asked to document how they used the Web to obtain the information. Finally, students were required to use ftp to obtain a data file from a local file server. While the latter two requirements maybe quite common place for many of us, they have been included in the project to make sure that the students are familiar with these mechanisms.

Assessment

A key factor in evaluating the students work is to put into place assessment mechanisms which maintain professional standards but do not unduly constrain the flexibility in the system. Each written assignment was reviewed thoroughly by the course instructor and comments were made directly on the students documents. It was noted that a "good" report may have as many comments as a "bad" report in that much of the feedback was being given in a constructive manner. A grading sheet was prepared for each of the assignments which identified the distribution of marks across the scope of the assignment. The sheet specifically identified design issues and concepts that needed to be addressed in that particular assignment. Comments were also included on this sheet to assist the students in learning from their mistakes. Since the communications aspects of the project were of great importance, report organization and presentation was always heavily weighted. Comments were specifically made on writing style, report organization good and bad presentation techniques, etc. The final layout and the project presentation were also graded from a communications perspective. Feedback was provided to help the student improve their skills in these areas. Students were encouraged to discuss the comments found in their reports with the instructor so as to maximize the learning experience obtained from the exercise.

Continuous Development

In the spirit of continuous improvement, there is still much to do. The two biggest problems that have been found when comparing goals with performance are in the areas of project management and teaming. Many students at this level of development are not prepared to take on a big project and see it through to completion. It was hoped that the limited scope and size of this project and the subdivision of the work into three separate assignments would make it more manageable. This has not proved to be a reality and more thought is needed as to how to assist the teams in project management without taking control away from them. The teaming aspects of the project were completely unstructured and left to occur naturally. Some up front information and advice to the students is needed in this area also.

There is a need to change the project from year to year. This year it was electronics, next year it will probably be unfinished furniture. With the significant amount of feedback and discussion that is being provided to the students, it is impossible to consider using the same problem description from one year to the next. Everybody would know "the answer" before you even distributed the information packages. However, given the size of the problem description and the students reports, there is little fear that a student will study an old assignment unless it closely parallels the current project. Creation of a new case each year constitutes a significant effort on the part of the faculty.

There are new issues and problems to be added that were not found in the current problems. For example, the current problem does not address the number and location of inspection points in a processing sequence. In an industry where there are a large number of out of spec parts, this issue is very important. New issues and problems will be added while other items are dropped. The authors of this paper encourage input from others who teach such a course to exchange information and projects. They can be reach via Internet at *deisenroth@vt.edu* or *ioannou@vt.edu.*

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