2006-1409: A STUDENT PROJECT EMERGING FROM A TRIPARTITE FACULTY COLLABORATION

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Introduction

Simultaneous engineering is principally geared toward accelerated product development through interdisciplinary teamwork. Organizations such as the Society of Manufacturing Engineers (SME) and the Accreditation Board for Engineering and Technology (ABET) have either directly or indirectly emphasized that undergraduates in the discipline should be well prepared in all aspects of teamwork and possess a certain degree of breadth and depth of exposure to various bodies of engineering that are exemplified in present day machines and consumer products[1,2].

Interdisciplinary projects have been used in engineering or engineering technology to augment instruction in capstone-type courses. Researchers in education generally agree that an integrated interdisciplinary curriculum results in greater enhanced problem-solving skills and higher achievement; and that motivation to learn increases when students focus on problems that are interesting to solve[3]. Other researchers such as Jeffries[4] and Kitto[5] have also emphasized how simultaneous engineering has become an agent for sweeping reforms in manufacturing education. Internationally, the integrated product and process development paradigm of simultaneous engineering has positively impacted manufacturing education in countries such as Australia, Brazil, China, and Japan in recent years[6-9]. Evidently, simultaneous engineering continues to be the norm in modern manufacturing education and hence a meaningful manufacturing engineering technology program should be aligned with needs of the industry. Indeed, this was the primary motivating force urging the authors to collaborate and conceive an interdisciplinary project.

Simultaneous engineering has been used interchangeably with other terms such as *integrated product and process design* (IPPD), *collaborative engineering*, and *concurrent engineering*. The phrase *simultaneous engineering* was adopted to describe the core of this project because it is arguably a more popular descriptive approach to better contrast the paradigm of the sequential engineering model that business and industry desired to replace during the past two decades. In addition, newer terms such as IPPD and collaborative engineering represented much smaller shifts in engineering and business practice when contrasted to simultaneous engineering versus sequential engineering.

The objectives of the student project developed by the authors were to provide students majoring in Electrical Engineering Technology, Manufacturing Engineering Technology, and Industrial Technology programs with an opportunity to simulate a competitive industry style product development scenario and educate them on the critical dimensions of a true simultaneous engineering experience. The critical dimensions were identified as collaboration (teamwork), multidisciplinary learning, project planning, time management, and advanced technology. Student teams drawn from three different courses (one from each program) were asked to develop a means to monitor people entering a public gathering space. The paper will discuss the implementation of this project, addressing all the above factors and lessons learned.

Previous initiatives and their relationships to the current project

In Fall 2002, the authors were funded by the Northern Illinois University's Council for Improvement of Undergraduate Education to develop interdisciplinary projects for a similar cause[10]. Examples of projects completed included an intelligent paintball hopper, a safe room in a residential building, an automated pill dispenser, active headlights, obstacle detection system, motorcycle gear position indicator, electric motorcycle, and a smart garage. Details of these projects can be found in Reference 10. From the results of this study, some significant shortcomings were observed. Although the authors were able to successfully simulate an integrated product development paradigm in their courses during that semester, this experience fell short of a true simultaneous engineering experience in one key aspect; the presence of direct competition between student teams that reflects a real world scenario. In addition, some shortcomings such as common meeting times and variety in complexity of product designs were identified. As a result of this, the authors decided to overcome these drawbacks by proposing that all teams solve an identical problem. This paper describes the details of how the project was implemented. However, the lack of a common meeting time for all three classes could not be overcome in this project and its impact is discussed later in this paper.

The new project

The objective of the new project was to provide students majoring in Technology with an opportunity to simulate a competitive product development scenario in an industry or business type environment, and educate them on the critical dimensions of a true simultaneous engineering experience. In contrast to the previous initiative, this project involved concept design only. That implied each student team needed to develop a basic design (with all the specifications and diagrams) for this product so that the design could be passed on for further implementation and quantity production. In addition to this, the student teams needed to work on the same problem (task), thus enabling competition among teams and a fairer evaluation. The student teams were required to submit a detailed final report documenting all details of the project.

From our prior initiative, it was evident that such team projects were time consuming. To address this problem, the project was divided into two parts. During the first part, the faculty worked together to identify, compile, and develop an on-line resource link for the project. This also involved the development of rubrics that were specifically related to this project. This part of the project was completed during Summer 2004. The second part which involved classroom implementation was completed during Fall 2004. The participant classes were:

TECH 414: Computer Aided Machine Design. (Dr. Bala)

TECH 420: Computer Integrated Manufacturing (Dr. Otieno)

TECH 430: Microcontroller Interfacing and Applications (Dr. Azad)

Electronic crowd monitoring system

The problem was defined as one of designing and developing an electronic crowd monitoring system for mass gathering places. This system was to count incoming and outgoing persons, and indicate the number of occupants through an electronic display, together with the remaining capacity of the location. The entrance door was to be locked automatically when the location is populated to its capacity. This system was to be designed to help the management of public gathering places to ensure that the capacity is not exceeded. In real life, this project had significant applications, for instance, in the event of evacuating a building during a fire or designing to match building safety codes.

Considering the nature of the project, students from each course needed to collaborate extensively for its successful completion. However, each class had a unique role to play, as described below.

Computer aided design aspect of the project – TECH 414

Firstly, this project was expected to expose the students to various models of the design process. The design process involved iteration, collaboration, interdisciplinary approach, and above all, from a business point of view, competition. Designing products with considerations such as enhanced functionality, manufacturability, ease of use, reliability, safety, disposal, and aesthetic appearance increase market appeal and the product launch is likely to be successful. A very important technological skill in today's product development environment is computer-aided design (CAD). Students were exposed to a wide range of skills through this project.

TECH 414 is a course that focuses on modeling machine parts and assemblies using a state-of-art CAD package (SolidWorks). Through this project, students were able to develop CAD skills while simultaneously bringing out their creativity and problem solving ability. By interacting with students enrolled in electronics and manufacturing courses, the CAD students were exposed to an industrial world scenario. The ability to compromise and optimize is an essential part of executing the design process. An important outcome of this project was the development and compilation a set of on-line learning tools. This specifically identified CAD resources that were useful in working with electronics and explored partner products that augmented typical CAD functionality.

Manufacturing aspect of the project - TECH 420

In TECH 420, the students will usually have learnt the basic manufacturing processes and materials from a prior prerequisite course. These skills were to be used in the project to determine what materials would best be used for building the casing for electronics and mounting the structure. After evaluating the functional requirements of the product, the students from this class performed a market survey and decided what annual quantity was appropriate to manufacture. Based on the manufacturing quantities the students decided: a) type of manufacturing strategy for the product and manufacturing method to be used; b) a layout of the manufacturing area; c) the machines and equipment to be used in the plant; d) the production control techniques; e) an estimate of unit cost of production and the market price of the product; and, f) an economic analysis to justify the unit cost of the product.

Electronics and control aspect of the project - TECH 430

This course addresses the design, development, and implementation of control systems using microcontrollers. To do this, a student has to learn about system design requirements, sensors, actuators, drivers, signal conditioners, microcontroller structure, interfacing, and assembly programming. In terms of contribution toward the project, the students from this class addressed the electronic and controller design, system accuracy and reliability, and performance. The electronic and controller design was divided into four major components: a) suitable sensor system; b) passing data to a system controller; c) electronic display system; and, d) interfacing between the display and the controller. The sensing system produced a signal for each individual entering or exiting the room/location. The sensor needed to be placed in such a way that it would avoid overlapping in counting. The sensor outputs needed to be processed to acceptable forms and levels before being transferred to the controller. The controller processed the data and the results were sent to the display through a suitable interfacing system. The display system was to indicate the number of occupants in the room/location and the available remaining capacity. In addition to these, the system controller was to initiate closure of the entrance door to avoid any further entry when the facility was full to its capacity.

Project implementation

The classroom implementation of this project involved the formation of student teams, collecting and dissemination of students' contract details, providing individual course time plans and overall project time plans, continuous evaluation of student progress, collaboration between faculty to monitor overall status of progress, and project evaluation.

There were six student project teams with three students each from TECH 420, and two each from TECH 430 and TECH 414 respectively. Students from individual classes were assigned their counterpart students from other classes. These project teams were formed with students of mixed abilities. However, measures were taken to ensure that there would be contribution from each team member towards the project. In addition to the abilities, students' availability times were also considered during the team formation. At the beginning of the semester each student was asked to fill an availability form, which included their possible team meeting times, contact email, and telephone numbers (Appendix-A). The information gathered was entered on an Excel sheet and provided to all the team members. In addition to this, each class previewed a video on interdisciplinary projects, titled "Simultaneous Engineering" produced by SME. This enabled them to learn about the industry-wide use of interdisciplinary project implementation techniques, and to understand the importance and benefits of this practice.

It is important to mention here that this project was a required part of each participant course. While implementing the semester long collaborative project the faculty needed to ensure the achievement of course objectives. With this in mind, each faculty developed a time plan for his respective course. In addition to the time plan, each class had its own grading criteria and deadlines for submitting interim reports. An example of the time plan, deadlines, and grading criteria for TECH 430 is provided in Appendix-B. The students needed to submit interim reports in a timely manner so that faculty could monitor their progress and provide summative assessment as students evolved through the semester. Apart from these, the individual class teams needed to submit a final report and provide an oral presentation. Students from other classes were also encouraged to attend these presentations.

In addition to the individual project time plan there was a global (overall project) time plan shared by all the classes. This global time plan indicated only the major goals and time points of data/information exchange between the team members of different classes. The global time plan is shown in Appendix-C. All the time plans, grading criteria, and deadlines were developed in close collaboration between the faculty members. The progress through the global time plan was also monitored by the faculty members. The faculty members met on a bi-weekly basis to review the progress of individual classes as well as the teams.

Active collaboration between the participant classes was one of the important factors towards the success of the project. Just after the formation of project teams, each team was to meet for a brief session for purposes of introductions and also discussing their concept about interdisciplinary project. Each team was to have a student leader and his/her responsibility was to organize the meetings and collaborate with the assigned faculty mentor. Around the end of the semester, the project teams were provided with a set of discussion questions (Appendix-D). These questions were formulated from each course subject area. Each of the teams were required to meet together to discuss and prepare a solution paper for the discussion questions (one solution for each team). In addition to the final report, the answers to these questions were used to evaluate students' understanding about the interdisciplinary nature of this project.

Conclusions and outcomes attained

Although students worked within the confines of individual courses through most of the design and development, there was significant evidence of collaboration through on-line mechanisms and meetings initiated by both faculty and students. Students were exposed to a typical product development paradigm prevailing in industry today. The activity provided them with a tangible experience of how events should be managed in sequential and simultaneous engineering models. A very significant part of the learning experience was a culminating activity where student teams were required to reflect on the overall project and respond to a series of carefully constructed items that were designed by the investigators (Appendix D). The authors were pleased with the quality of design ideas that were presented and how students approached problem solving. The student team projects were ranked according to how they reflected potential product success in the marketplace.

A brief end of the semester evaluation also provided evidence that students appreciated the spirit of the project and expressed an interest in having more interdisciplinary projects during their tenure at the university. Their reservations were primarily directed towards the difficulty in getting together as the three courses met at different times. Not surprisingly, there was some amount of blame placed on individuals from other courses. This is not essentially a negative indicator, as such feelings are commonplace even in professional settings. From our perspective, interdisciplinary projects involve significant time investment and logistical challenges. However, we believe that this project provided a stepping stone for students from different disciplines to strike active partnerships, and hopefully, this positive experience could lead to more high quality interdisciplinary projects in the near future.

References

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Appendix-A

Department of Technology

College of Engineering and Engineering Technology
Northern Illinois University

Interdisciplinary Project Learner Profile and Semester Availability

Course Number: ____, Fall 2004

Name (First, Last)____

Please check the appropriate box: ☐ Graduate ☐ Undergraduate

Contact phone ___________________ E-mail ____________________________

Times UNAVAILABLE for group-work:
In the chart below, please cross out times when you will **NOT** be available to work outside class on assignments with your group. Mark only genuine conflicts, such as class time or work hours.

Time	Mon	Tue	Wed	Thu	Fri	Sat	Sun
8-9 a.m.							
9-10							
10-11							
11-12							
12-1 p.m.							
1-2							
2-3							
3-4							
4-5							
5-6							
6-7							
7-8							
8-9							
9-10							

Other information you'd like to share regarding your ability to function as a team member this semester (You may write on the other side if required):

Appendix-B

Time Plan and other details for TECH 430 (Interdisciplinary Project)

	Tasks	W1	W2	W3	W4	W5	W6	W7	W8	W9(	W10	W11	W12	W13	W14
1	System block diagram														
2	General selection of system components														Evalua tion
3	Specific selection of components														Week
4	Connection diagram between all the parts														
5	Program flow chart														
6	Program modules														
7	Testing of whole program														
8	Report														Report

Blue color indicates receiving data from violet color indicates passing data to Tech420

Mark distribution

Evidence of group dynamics 10

Interim reports 30

Final paper 40

Presentation 20

Appendix-C

Global time plan (Interdisciplinary Project)

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Tech 414														
														Evaluation
Tech 430														Weel
Tech 420														

Tech414: Start work from W1(8/30) and will pass data to counterpart groups in Tech 430 and Tech 420 on W5(9/27).

Tech 430: Start from W1(8/30) and will receive data from counterpart groups in Tech 414 on W5(9/27) They need to pass data to counterpart groups in Tech 414 and Tech 420 on W7(10/11). Will continue to work until the end.

Tech 420: Start work from W5(9/27) after receiving initial data from Tech 414. They will receive further data from the counterpart groups at Tech 430 on W7(10/11) and will continue to work until the end. They will work further two weeks and pass data to the counterpart group members in Tech 414 and Tech 430 on W7(10/11)

Evaluation: Separate evaluation plan will be provided by the course teachers. However, groups from all the courses need to complete their work by W13 (11/22). Each group need to submit a final report by 29th of November 2004.

Fall 2004

Appendix-D

Interdisciplinary Project

Participant Classes: Tech 414, Tech 420, and Tech 430
Discussion Questions

Please read the following note before answering these questions.

IMPORTANT: All these questions are related to your interdisciplinary project. The questions cover topics from all the three participant courses. For some questions (which are not from your course topics), you need to consult with your partners from other classes.

Question 1: What type of devices can be used to display the number of occupants (within the space under consideration)? Please explain their operating principle (in general terms).

Question 2: What are the possible devices or components that one can use to count the incoming and outgoing audiences?

Question 3: To control the proposed system, what are the possible candidates for an electronic controller? Highlight the advantage of each.

Question 4: After the system is developed (proposed interdisciplinary project), what will the total electric power consumption for the proposed system? Please specify a range and show a breakdown for the consumption.

Question 5: Describe a typical model of the engineering design process with at least six distinct stages clearly noted.

Question 6: What are all the advantages of using a simultaneous engineering approach compared to sequential engineering?

Question 7: The required production rate for your electronic device is 400 units a day (2 shifts/day, 200 days per year). An operator is paid $7.5 an hour while each machine on the average will cost $450 to set up and $0.35 a minute to run.

- List a sequence of processes/operations you need to assemble your device, and in each case, state the type of machine (e.g. robot) you would use for the process.
- What kind of layout and materials handling facilities would you select for the production of this device?
- Estimate a minimum unit production cost for the part.
- What appropriate tools/techniques would you employ to track your part as the raw materials come into the plant and the finished part is boxed?
- How would you ensure the parts are defect free?

Question 8: Describe a typical model of the engineering design process with at least six distinct stages clearly noted.

Question 9: What are all the advantages of using a simultaneous engineering approach compared to sequential engineering?

Question10: There is a report in Metro, Tuesday, October 19, 2004. The title of the report is "*Bar fined $500 for over-occupancy*" (a copy of this report is attached). Does the team feel that its concept design would address a situation similar to this?