INTERDISCIPLINARY STUDENT PROJECTS TOWARDS SIMULTANEOUS ENGINEERING: LEARNING AND ISSUES BROUGHT FORWARD

Abul K. M. Azad[1], Andrew Otieno[1] and Radha Balamuralikrishna[1]

Abstract: In recent times, engineering and engineering technology leaders have a renewed sense of urgency in implementing practice-oriented education. It has been urged that both selection of topics and instructional methods be more inclined towards industrial practice. A major shift in product development practice in industry during the past two decades has been towards simultaneous engineering. Therefore, a significant number of engineering educators have diligently worked to emulate simultaneous engineering principles and concepts in their classrooms. This paper captures the authors' efforts to initiate a collaborative interdisciplinary project with a long term view towards fostering and blending simultaneous engineering into the engineering technology curriculum at Northern Illinois University.

INTRODUCTION

The principles and practice of simultaneous engineering are primarily geared towards accelerated product development through intelligent teamwork and networking of interdisciplinary teams. Educational programs oriented institutions such as the Accreditation Board for Engineering and Technology (ABET), the Institute of Electrical and Electronic Engineers (IEEE), and the Society of Manufacturing Engineers (SME) have proclaimed that undergraduates in engineering and technology disciplines should be well prepared in all aspects of teamwork, and possess interdisciplinary skills in order to function effectively in today's industrial environment which has diverse machines and consumer products [1].

A successful engineering technology program should be aligned with the needs of industry; this was the primary motivating force urging the authors to collaborate and create a platform for initiating a simultaneous engineering learning experience. It was decided that the first steps in this direction should assume the form of an interdisciplinary project. This paper presents the learning from this initiative highlighting the relevance of the project, logistics, and outcomes both from the perspective of students and the authors. This presentation will also focus on the challenges of conducting such collaborative projects and outline measures that foster success. We would also like to point out some potential pitfalls and pave the way for other interested instructors to engage in even more successful implementation of interdisciplinary projects at their institutions.

WHY INTERDISCIPLINARY PROJECT ?

Although the College of Engineering and Engineering Technology (CEET) at Northern Illinois University (NIU) encourages the paradigm of simultaneous engineering and its incorporation in instructional practice, there has been no formal initiative towards this effort [2]. The Technology Department at NIU currently offers courses in three areas of specialization, Electrical Engineering Technology (EET), Manufacturing Engineering Technology (MET) and Industrial Technology (IT). One of NIU's internal funding agencies that specifically focuses on increasing the quality of undergraduate education supported the authors' joint proposal towards the launching of an initiative that increased simultaneous engineering awareness among its student population. Under this initiative, EET, MET and IT students enrolled in three different courses were asked to complete an interdisciplinary project towards partial fulfillment of their course requirements. The proposal was accepted in Summer 2002 for implementation during the Fall 2002 semester.

Interdisciplinary projects have emerged as one of the hallmarks of simultaneous engineering oriented education. A significant number of educator teams have successfully conducted interdisciplinary projects at institutions both in the United States and abroad. Through their individual case studies, Jeffries [3] and Kitto [4] have described at length their efforts to blend simultaneous engineering in undergraduate engineering education. 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 [5]-[9]. Teamwork and collaboration among professionals drawn from different disciplines are the keys to product success, and it is imperative for engineering and technology educators to address this issue in order to ensure the continuing success of our profession [10].

PROJECT PLANNING

Students enrolled in selected courses that the collaborating faculty members offered during the Fall 2002 semester were challenged to work cooperatively on a project of their choice.

[1] Department of Technology, Northern Illinois University, DeKalb, IL-60115, email: azad@ceet.niu.edu

The requirement for the project was that it had to contain at least one major component that would require utilization of skills derived from each of the three courses under consideration. The courses are Tech-414: Computer Aided Machine Design, Tech-420: Computer Integrated Manufacturing, and Tech-430: Microcomputer Interfacing and Applications. The project ideas that the students could conceive was open to existing, new, or improved products.

After an availability survey was carried out in the three classes, nine student teams were formed. The group composition was: 3 to 4 students from Tech-430, 1 or 2 from Tech-420, and one from Tech-414. Each group was required to submit a draft proposal to complete an integrated project by the end of the third week of the semester. After being reviewed, the proposals were returned to the student teams with comments and suggestions for necessary changes. The teams were then required to submit a final proposal within a week's time. The authors approved the proposals after due consideration of the scope of the project and its feasibility with regard to the available resources.

Each group was assigned to one of the authors as their *primary point of contact.* The student teams then went through their project planning, identifying required parts and components, ordering items, and project integration. Although the authors discussed the projects during their own class hours, there was no common time where the authors could meet with all members of any given team. In that sense, these were mainly student driven projects as the students had to learn to function as teams without direct faculty support. The student teams were asked to consult with their *primary point of contact* if they felt they wanted to bring up any issue that was hampering their progress through the project. Although there was no formal arrangement for any helping hand to the students towards this project, from time-to-time help was provided through teaching assistants.

At the end of the project each team was required to give an oral presentation and demonstrate their working product to their peers and the faculty involved. The audience was meant to include all the students enrolled in these classes. In addition, they were also required to submit a written report. The written reports varied from 8 to 10 pages. The allocated time for this presentation and product demo was 30 minutes for each team. For assessment purposes, points were allocated for each of these activities.

ILLUSTRATIVE EXAMPLES

This section discusses the general nature of the projects along with their outcomes. A total of nine projects were pursued through this initiative. Each of these projects was aimed at developing a product, which is related to a real-life problem. The students were required to create solid models using a computer-aided design (CAD) system to document their design ideas. In some cases, schematic drawings were used exclusively or to augment the models. It was clear that all student projects involved a certain degree of understanding and application of automation technologies such as the use of microcontrollers, programmable logic controllers, transducers, actuators, system controllers and electronic interfacing. These skills were used as required to realize the intended functions of the designs. Each project team was required to think in terms of system accuracy, reliability, and performance in general.

It was felt that the students experienced more relevant and enhanced learning through their interdisciplinary project than would have occurred through structured and compartmentalized problem solving in their individual courses. Due to time limitation and other factors, some of the student groups did not manage to get through the system integration part. However, all the groups but one demonstrated working models and designed parts for the prototype system. Brief descriptions of four projects (below) indicate the enthusiasm, creativity, and innovativeness of the student project teams.

a) Design and development of a Paintball Hopper

The need for speed is a big part of many athletic/sporting events and recreational activities. The sport of paintball is no different. Paintball guns can shoot as fast as the person pulls the trigger, but paintballs can only fall as fast as gravity allows. The purpose of this project was to produce an improved paintball gun that utilizes an electronic system to optimize paintball ejection. The system comprised of a microcontroller board, motor, ball system, LCD display, an electronic interface between the LCD and system, and a container. Figures 1 and 2 show the system as demonstrated by a student group.

FIGURE 1
PROTOTYPE CASE AND SOME ELECTRONIC PARTS FOR MC HOPPER

FIGURE. 2
ELECTRONICS FOR PAINTBALL HOPPER SYSTEM. ALONG WITH A PART OF CASING.

b) Design of a safe-room within a house.

The safe room is a hidden room that will protect a family or its members in case of any threat from an intruder. This system was designed to have several safety switches around the house, mainly on the doors and windows.

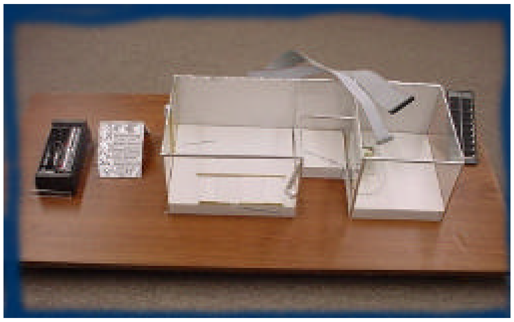

FIGURE. 3
SAFE ROOM SYSTEM SHOWING SOLAR CELL AND CABLING.

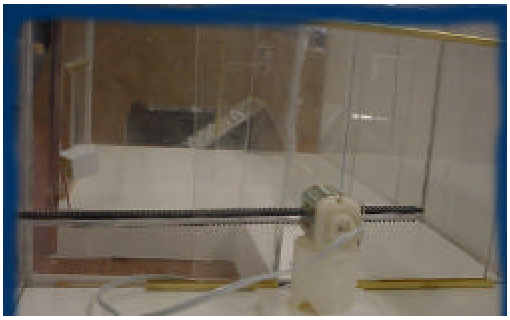

FIGURE. 4
MECHANISM FOR DOOR MOVEMENT FOR THE SAFE ROOM.

If there is an intrusion at any of those points an indicator will glow. At this point, the family members can move into the safe room and the door of the room will be locked automatically and allow the members to contact the outside world. The designed system consists of a sensing system (door contacts, motion detectors, window sensors, glass breaking sensors) and a motor control system for the safe room door movement. The system is powered through a solar cell and backup battery. The picture of the developed system is shown in Figures 3 and 4.

c) Motorcycle gear position indicator

The typical motorcycle has 5 or 6 forward gears. However, for the rider the only indication of what gear the bike is presently in is the neutral light, which illuminates only when neutral is selected. Due to lack of any indicator, there is no way for the rider to know what gear the motorcycle is in unless the rider mentally keeps track. Keeping track of the gear position is important, especially for the novice rider who is learning what gear corresponds to what engine rpm and road speed. With the developed device, the rider will be able to identify the current gear position through a set of LED indicators. The system consists of a microcontroller system, gear switching box, and a suitable interfacing circuit. The electronics parts for this project are shown in figure 6 below.

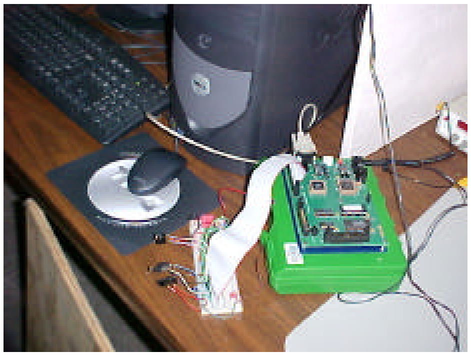

FIGURE. 6
ELECTRONICS DESIGNED FOR MOTORCYCLE GEAR DETECTION SYSTEM.

d) Automated pill dispenser

The pill dispenser delivers the prescribed number of pills at any specified time. A prototype of this project is shown in Figure 7. The systems consisted of a pill container that has six different compartments all spanning around a motor shaft that will drive a lid.

At the appropriate time a buzzer will sound and a green light would come on to let the consumer know that it is time to take the next dose. The consumer will then press a push-button switch. Once the switch is pushed, the buzzer and green lights would go off. A lid will rotate allowing the pills to drop out from a hole under the container. This is repeated whenever it is time to take the pills. The developed system contains a stepper motor that activated the dispensing system, a PLC that controlled the timing and stepper motor rotation, the dispensing unit, and an indication system.

FIGURE. 7
PROTOTYPE OF THE AUTOMATIC PILL DISPENSING SYSTEM.

STUDENT EVALUATION

At the end of the semester, a paper and pencil survey instrument was administered to each student to assess the impact of interdisciplinary team projects on student learning outcomes. This survey is a modified version of the standard course evaluation questionnaire used by the Department of Technology at the end of every semester. It consisted of 10 questions for which the students were asked to rate using a scale of A (excellent or very adequate), B (good or somewhat adequate), C (average or somewhat inadequately), D (fair or very inadequately) or E (poor or does not apply). Table 1 summarizes the questions that were posed in the survey instrument along with the summary of the responses from the 42 students that participated in the survey. Also in the questionnaire were other open-ended items that provided students with an opportunity to render detailed remarks about their experiences, important lessons learned, and any changes they would recommend if they were to participate in a similar project in the future.

TABLE 1. SUMMARY OF ASSESSMENT QUESTIONS AND STUDENT RESPONSES.

	Item Theme	**Student Responses (%)**				
Question #		A	B	C	D	E
1	Organization of the projects	3	38	29	15	14
2	Learning experience undergone in terms of working with diverse teams in a simultaneous engineering oriented environment.	10	53	29	7	0
3	Relevance and importance of the knowledge you gained in individual course to the successful implementation of this project	21	29	30	15	5
4	Use knowledge to engage in scientific inquiry to implement project	14	73	12	0	1
5	Use knowledge to engage in creative thinking at the design stage and throughout project implementation	36	56	8	0	0
6	Use knowledge to engage in critical thinking	26	65	8	0	0
7	Use knowledge of science and math to engage in designing and implementing project.	11	82	5	1	0
8	Synthesis of knowledge derived from varied disciplines in order to complete project	10	61	28	1	0
9	Effectively utilize communication skills.	39	46	8	3	3
10	Functionality of the group	49	40	11	0	0

The results shown here indicate that most students had a positive learning experience. A good percentage of students indicated that the level of organization was good (38%) or excellent (3%), however the majority felt it was average (29%), fair (15%) or poor (14%). This may be attributed to the fact the projects were funded from a very tight departmental budget originating from student course fees. Another observation in the students' comments is the fact that the three different classes met at different times on different days and this posed a problem for the students to arrange a common time to meet, especially those with full time employment. In addition, this being the first attempt at such a venture, the project instructions and grading rubrics were not as comprehensive and concise as they should be to provide students with a clear understanding of what direction they ought to take for the project. Despite the organizational problems, nearly all the groups worked together smoothly. Half of the students felt their teams were very functional and another 40% felt their teams were functional; this indicates that the simultaneous oriented engineering approach can be used within a limited resource environment to undertake major projects successfully.

The skill requirements that scored highest in the "very adequately" utilized category were communication skills (39%)

followed by creative thinking (36%) and critical thinking (26%). Indeed many students in their comments attested to the fact that either their communications skills or need for good communication skills were very important to get the team members working together. It is also evident from these results that for the successful completion of the projects, most students found their knowledge of math and science, and their scientific inquiry very adequately or adequately utilized to design and complete their projects. Another significant result from the assessment is the relevance of the students' individual courses to the successful completion of the project. Only 21% thought what they learned in their courses was very relevant to their project, while about 30% felt it was relevant or fairly relevant. In contrast to this scenario, the majority of the students felt that synthesis between the skills acquired in their individual courses and various skills required for the project was very adequately (10%) or adequately (61%) achieved. These results clearly indicate that the project goals were met.

Any successful team project must rely on effective communication between team members. Moreover the success of a simultaneous engineering oriented project must rely on team members being proactive and ready to learn new skills and learn from each other. In one of the comments, a student confessed that he had never learned how to machine a part but at the end of the project he became "…an expert" in machining. Significant correlations were also found between the use of science and math and scientific inquiry, critical thinking and creative thinking, and how the students synthesized the different bodies of knowledge required for the project with scientific inquiry, critical thinking, science and math and their learning experiences.

LESSONS LEARNED

Through student evaluation, project evaluation and observations from student group dynamics it was realized that there are several factors, which could have done differently to enhance the project outcomes. A brief discussion on these factors along with what could be done better is given below.

a) *Common meeting time:* Students in the three classes did not have the privilege of having a common meeting time because the classes were held at different times on different days of the week. Each student therefore had to make significant changes in their personal schedule to make things happen. For any future offering of such project, it is important to schedule a common meeting time for all the classes.

b) *Project budget:* The money available to complete each project was only $75. Therefore, students had to conceive a project with the limited budget under consideration. However, one project team was able to acquire free supplies through industry support and personal research. It is important to increase the budget or to offer projects, which can be completed within a limited budget.

c) *Assistance towards the project:* Apart from scheduled contact hours with respective course instructors there was no planned technical assistance towards these projects. Students groups had to find their own way of working through the project. It would be a good idea to provide technical help through teaching assistants.

d) *Faculty supervision:* As mentioned before, the authors were available to the student teams whenever they needed help. However considering the fact that these teams were from different classes that met on different days, it was important to schedule a weekly or fortnightly meeting with the respective teams as a whole.

For any future initiative of this nature the above issues need to be addressed to enhance the project outcomes.

CONCLUSIONS

An account towards the design and offering of interdisciplinary simultaneous engineering projects has been presented. The initiative achieved considerable success. The preliminary study showed strong signs that integrated design projects provided a fulfilling learning experience for students. The authors feel that these learning experiences were invaluable and should augur well for students who proactively engaged themselves in these activities. Challenges and difficulties are to be expected. These projects require significant financial investment for materials and supplies used in constructing prototypes, and considerable investment of faculty time as well. Issues that arise with ill-structured problem solving may not be received equally well by all students, however, our experiences were very positive. We believe that our initial planning and continued support extended to project teams helped things run as smoothly as they did. It is highly important that collaborating student teams have the opportunity to meet at a common time dictated by the scheduling of classes. Given this opportunity, it is highly probable that our students would have fared even better.

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