Teaching IPPD and Teamwork in an Engineering Design Course*

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Abstract

In response to the needs of industry, college/university courses must help engineering students to be effective members of diverse teams, to be aware of industry practice, and to understand the product life cycle. This paper highlights our new teamwork-oriented curriculum, our methods for assessment, and our current results.

1. Introduction

The emphasis of many companies is moving towards Integrated Product and Process Development (IPPD), in which engineers work in multi-disciplinary teams in order to create a product with higher reliability, shorter production time, lower cost and a concern for the environment. Recent reports [3] [4] suggest that college/university curriculum should begin to address the current industry needs for IPPD training. More specifically, engineering courses should enable students to be effective members of diverse teams, to be aware of industry practice, and to understand the product life cycle. Over the past four semesters, the Engineering Academy of Southern New England (EASNE) supported our efforts to develop a new and innovative course structure with an emphasis on IPPD.

This paper highlights our new IPPD/teamwork curriculum, our methods for evaluation, and our current results. The paper focuses on the incorporation of teamwork concepts in a sophomore-level digital design course which is taken as part of the computer engineering course sequence. Many of the concepts, such as team cooperation and team design are applicable to other fields of engineering.

2. Curriculum Goals

To define the high level goals of the new curriculum, we contacted engineers and managers from our local industry. An informal survey was conducted in which we asked them to identify the topics of greatest importance to the education of graduating engineers. It was clear from the informal survey results that our design coursework could benefit from projects to address both manufacturing and teamwork issues.

In all our discussions with industry personnel one point was stressed: design engineers must incorporate manufacturing considerations *early in the design process*. Failure to do this may lead to a product which cannot be manufactured, or can only be manufactured at a very high cost. Manufacturing cost is critical in a competitive commercial setting, therefore the engineering student must be aware of the final cost factors which are influenced by the design. The details of our manufacturing coursework are described in [6] and we will focus, for the rest of this paper, on the teamwork area.

We have conducted an extensive process of collecting information from a variety of sources in order to understand the expectations of current graduating engineers. With this knowledge, we created new goals for the engineering coursework, weighing both the importance of each concept, and our ability to teach it. The course we targeted for modification was the sophomore-level digital design course, which is a taken by all computer engineering majors at the University of Connecticut. The new goals for the course are summarized below:

- Integrate manufacturing, teamwork, and modern product development into the course by developing a teamwork project and a manufacturing project.
- Incorporate the interplay between design decisions and manufacturing of a design into course projects.
- Preserve any skills which are pre-requisites for latter coursework. New skills should re-enforce the fundamental design methods from the original course, not replace or eliminate them.

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3. Teamwork Curriculum

To form the basis of the teamwork skills development, we obtained an Integrated Product and Process Development (IPPD) team training outline from our industrial contacts [1]. The training outline provides guidelines for preparing engineers in industry to work as team members in a manufacturing-oriented environment. The IPPD approach is defined in the training outline as follows:

"The design, development, production and support of a product using multi-discipline teams working together to ensure concurrent integration of all requirements to achieve a mature product with high delivered quality, high reliability, and low life cycle cost in the shortest possible time."

Some of the primary concepts which are introduced in the training outline are:

Cost factors for change: This area concerns the fact that changes in a product design become increasingly more expensive to a company as they are made latter in the design and development process.

Concurrent engineering: This area concerns the efficient scheduling of product creation addressing the inter-relationships between teamwork, design, rapid prototyping, testing, manufacture and assembly [2].

Robust design: This area concerns the design of a product which is tolerant to variation in the user inputs, environmental inputs or manufacturing processes.

Shared responsibility: This area concerns the commitment of each team member to the goals and success of a team project at all levels.

Leadership decision styles: This area concerns the organization of team management and the process by which design options are selected.

Managing team conflict: This area concerns the resolution of interpersonal, technical or leadership arguments between team members.

Team communication: This area concerns the understanding of how people in a team communicate and what can be done to improve interaction.

Effective team meeting: This area concerns the basic elements of a productive meeting and identifies the causes of wasted time.

One approach is to use the training outline for one or more class periods and also develop a separate laboratory project which brings these issues to the surface. It is important to introduce the teamwork and communication issues before the students actually begin a teamwork-oriented project, so they can be prepared to resolve conflicts and structure the tasks right from the beginning. In our environment, teamwork training was presented as interactive exercise without the pressure of grading or assessment.

4. Teamwork Project

4.1 Goals and Structure

To incorporate IPPD skills into the course, we not only provided lectures and guest speakers from industry, but also developed a 3-week team project of size suitable for 3-4 person teams. The students were required to partition a large design among team members and integrate the separate sub-modules into a successful working circuit. The teamwork emphasis was intended to enhance the following specific areas of the curriculum:

1. Partitioning a large project amongteam members.
2. Designing a sub-portion of a project in a modular fashion.
3. Interfacing modules designed by different team members.
4. Testing a system which involves modules designed by different team members.

Members of the teams were randomly assigned, however we allowed students to work with friends, if they preferred. The assignment stated requirements for the project and also a functional overview of the operation of the system. From this description, the students defined detailed specifications, and then proceeded with design activities. In order to help the students overcome the initial complexity of the project, we suggested methods of partitioning the design to balance the workload.

4.2 Student Feedback

To understand the function of student teams and expose areas for improvement, we asked the students to report on their experience in a variety of ways. First, each student wrote a *Self-Evaluation* as part of their project report. The self-evaluation provides an opportunity for students to examine and assess their own performance as members of the team. Self-evaluation is an important step in the meta-learning process [5], and can provide valuable insights which help students overcome their learning obstacles. The student self-evaluation section can include a discussion of issues such as :

- How did the student promote the goals of the team and how would he/she rate their contribution.

- What problems were encountered and what were the causes.
- What could have been done to overcome the problems.
- What role did the student play within the group, i.e. team leader, team worker, team coordinator, etc.

A second section of the report, called the *Discussion Section*, is used as an open forum for discussing any issues the student wants to recount about the project. The discussion section includes descriptions of problems, insights, learning experiences, and opinions about equipment, teaching methods, and project structure. Instructors can make tremendous improvements in their course curriculum and teaching methods by taking a serious look at the comments made in the discussion section.

The third feedback section is a *Team Meeting Log*, which records the details of each team meeting. The meeting log includes meeting times/dates, number of hours spent, participants and work accomplished. The meeting logs provide an important feedback mechanism to the instructor for determining what led to the success or failure of a particular group.

4.3 Teamwork Grading Scheme

There are many unpredictable variables in a team project, thus students do not typically feel comfortable about having their grades determined by the actions of others. In addition, the team must overcome a relatively complex implementation task, thus an entire team's grades may be brought down by a single physical error such as a broken wire or faulty power connection. To resolve these potential grading problems, we devised a special grading scheme, which includes some degree of individual student assessment. In this scheme, 50% of the score is allocated to success of the final team circuit utilizing three deadlines. By utilizing three deadlines, students can miss the initial deadline, and still retain some percentage of the score. The remaining 50% of the score is allocated to areas that the individual students can control such as design documentation. The scoring breakdown is shown below:

Individual Student Scoring:	
Detailed Written specifications	20%
Design Report	20%
Self-evaluation, Discussion, Meeting Log	10%
Team Project Scoring:	
Project works by the 1st deadline	50%
Project works by the 2nd deadline	40%
Project works by the 3rd deadline	30%

Project not working after 3rd deadline: Assessed based on level of functionality.

5. Assessment of Teamwork Project

5.1 Data Collection and Results

What is the motivation for collecting data about the student learning process? Primarily to use the data as the basis for improvement and refinement of the course. In addition, the students appreciate knowing their opinions make a difference and that other students can benefit from their experience. In many cases, the students understand a project better than instructor because the teamwork factors are difficult to predict or simulate before running the course.

In the first pass of analyzing feedback data, we had no idea what we were looking for, which made it difficult to assemble a survey or questionnaire with pre-defined answers. Instead, we read and analyzed the written descriptions of the teamwork process supplied by students. The feedback was obtained from the self-evaluation, discussion section and meeting logs, which reside in the student reports. After reading through all the student reports, two significant areas for study emerged. In the first study, we wanted to discover the relationship between the number of team meetings and the success of the team. Data from the first study did not yield any significant insights so we will focus on the second study for the rest of this section.

In the second study, we tried to uncover the teamwork aspects which gave the students the most difficulty during the project. To begin the analysis, we studied the principal teamwork areas to discover which imposed the largest obstacles for students during the spring/fall 1995 semesters. To collect the data, each of the 46 reports was scanned to see if the student cited any of the following nine areas as major obstacles for the success of the project:

1. Conducting and arranging effective *team meetings*.
2. *Communicating* design information between teammates.
3. Resolving interpersonal, technical or leadership *team conflicts*.
4. Insuring that all members shared *responsibility* for the project.
5. *Partitioning* the project among team members.
6. *Designing* a sub-module of the project.

7. *Interfacing* the separate sub-modules using formal interface specifications.
8. *Testing* the system during the integration process.
9. *Implementing* the team design using protoboards, wires and integrated circuits.

Figure 1 shows the percentage of reports which cited significant problems in one or more of the nine areas.

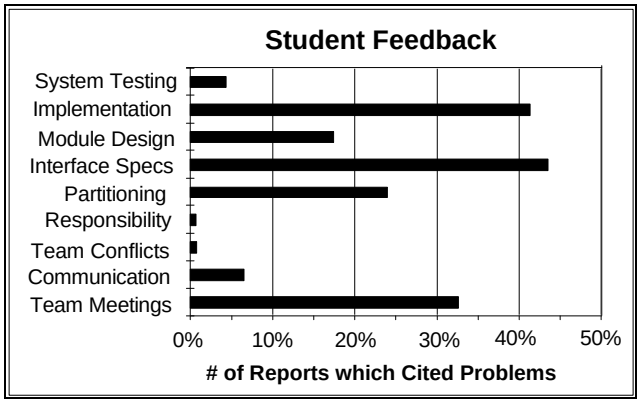

Figure 1. Student Feedback on the Teamwork Project.

5.2 Evaluation and Improvement

There were several specific insights gained from analyzing the student feedback and reading comments in the reports as described below:

- Most groups had good leadership - very few of the reports cited problems with team conflicts.
- Many groups cited problems with arrangement of meetings due to schedule conflicts, off-campus jobs, off-campus housing, etc.
- Many groups cited problems with inter-module interface specifications, primarily in defining the interface needed to connect sub-modules.
- Many groups cited problems with partitioning the project such that all members had modules of roughly equal complexity.

We are now in the process of deciding how to improve the course for the upcoming semesters based on the feedback information. Some potential solutions are described next. For problems with arrangement of meetings: allocate class meeting times as pre-defined team meetings and encourage the use of email for communication. For inter-module specifications: have instructor review the specifications in detail before allowing the team to proceed. For partitioning problems: encourage groups to dynamically adjust the partitioning as they uncover details through the hierarchical decomposition of the system design.

6. Conclusions

Our students need to learn the IPPD skills which are required in the emerging, highly concurrent engineering/manufacturing environment. Engineering projects are usually technological in nature or application, however many of the bottlenecks in the design process can be traced back to teamwork obstacles. In response to current conditions, a new engineering curriculum should be deployed to produce graduates with teamwork skills. Ideally, the new curriculum exists in a state of continuous evaluation, using the feedback from students to make improvements and adapt to new problems as they arise.

References

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