Course Collaboration in IE: Bringing the Reality of Teaming Into the Classroom

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Abstract

This paper presents an overview of the collaboration between Industrial Engineering juniors and seniors at Mississippi State University. The framework for the collaboration consists of two required courses, Design of Industrial Systems, the capstone design course, and Manufacturing Processes, a course in the curriculum junior year. The collaboration is accomplished through project teams in both courses, with students in the senior course serving as leader-liaisons to the junior teams.

Background

"Team learning is vital because teams, and not individuals, are the fundamental learning unit in modern organizations. " Peter Senge[1]

Design of Industrial Systems is the five-hour (two lecture, eight laboratory) capstone design course in the Industrial Engineering (IE) curriculum at Mississippi State University. In the course, students are formed into project teams with typically five or six students per team. Each project team selects a single manufactured product to analyze as part of a comprehensive venture analysis. The team must design and locate a facility to manufacture the product, including a detailed financial analysis for the first five years of operation. The product must contain significant fabrication and assembly content. (Occasionally a team is permitted to select a service industry project rather than a manufactured product.)

Each member of a project team is responsible for two functional areas. Example functional areas are marketing, safety, material handling, facility site selection, product analysis, facility layout and financial analysis[2]. Ten to twelve functional teams are formed to provide a means for students who are responsible for the same functional area to work together. Each student is a member of two functional teams.

Course Expectations

The Design of Industrial Systems course instructor acts as both the client and mentor to the project teams. The client is presented as a non-engineer entrepreneur. A client letter of authorization to each project team early in the semester informs the team of project parameters, expectations and deliverables. To provide a reasonable project scope for a sixteen-week semester, the client provides directions to the project team concerning product complexity and facility expansion considerations, and guidance on the financial analysis by providing a financial analysis spreadsheet.

The deliverables from each project team include a project proposal, with budget, early in the semester, a detailed facility layout, a detailed financial analysis for the first five years of operation, and various functional area formal reports, progress reports, and memos. A formal oral presentation of project results is made at the end of the semester to a panel of practicing engineers for evaluation of the technical aspects of the project analyses.

Portions of the required analyses in the Design of Industrial Systems class are subcontracted to other classes in IE, Mechanical Engineering, and/or Management & Information Systems in the College of Business and Industry.

Team Operation

A project officially begins when the client letter of authorization is delivered to each team, which selects both a team leader and project manager. The team leader is responsible for all team activities and provides leadership as necessary to achieve team goals. The project manager, in consultation with the team leader as needed, is responsible for project scheduling, budgeting, and cost monitoring and reporting.

A key component of the course is a weekly project team meeting with the client/mentor to review project status. The meeting chair and scribe rotate among team members for leadership experience. Written or electronic agendas and minutes must be prepared by the teams before and after meetings, respectively.

Grading

Each student's grade in the Design of Industrial Systems course is weighted as shown in Table 1. Note that team grades account for over half (56%) of each student's grade in the course.

Table 1. Design of Industrial Systems Grade Weighting

Individual Grades	
Tests	20%
Written reports	24%
Team Grades	
Oral presentation	16%
Project log	10%
Facility layout	30%
TOTAL	100%

Grades can also be affected by up to two letter grades by the project team peer review, conducted at the end of the semester. The peer evaluation form for a five-person team is given in Figure 1.

Figure 1. Peer Evaluation Form (Five-Person Team).

The purpose of this form is to obtain an evaluation from you of the relative contributions of you and the other members of your project team to the team's project work. Consider each factor below, then assign points to each project team member, including yourself, so that:

1. the sum of the points assigned is 100.
2. each point assignment reflects your opinion of the team member's contributions to the project, with the higher the score the more favorable the evaluation. In most cases, the assignment of the same points to each team member will indicate that you have not yet given this enough thought.

Be objective; do not allow personality traits to cloud your evaluation of someone's performance, either positively or negatively. This can be difficult, but it is necessary so that this activity is done in a professional manner. This is good experience for peer, superior, and/or subordinate evaluations you may be doing someday.

The results of your point assignments below may well affect someone's final grade, so please give this task serious consideration. Consider the following factors:

Dependability and Punctuality. Did the team member (TM) do what the TM committed to do? Did the TM attend team meetings and was the TM available when needed? Did the TM pull his/her weight?

Communication. Did the TM generally maintain awareness of the information needed by others on the team and provide it in a timely manner so as not to cause work delays? Was the information communicated complete, correct and well done?

Effort and Flexibility. Did the TM do a fair share of the work throughout the semester? Did the TM participate appropriately in group efforts and assist others when needed?

Behavior and Positive Attitude. Did the TM's behavior and attitude contribute to team effectiveness?

Project team member (write each name below)	**Points**
1. (you)	
2.	
3.	
4.	
5.	
TOTAL	**100**

Summary of the Collaborations

Project teams that perform a venture analysis for manufactured products collaborate with the two IE classes Manufacturing Processes and Engineering Administration, and with the Mechanical Systems Design class in Mechanical Engineering. Service industry project teams collaborate only with the Engineering Administration class and a class in Structured Systems Analysis and Design in the Department of Management & Information Systems, part of the College of Business and Industry.

The various collaborations are summarized in Table 2. In following sections the Manufacturing Processes collaboration, the focus of this paper, is described.

Table 2. Collaborative Courses.

Collaborative Course	**Responsibilities of Collaborators**
IE 3323 Manufacturing Processes Department of Industrial Engineering	Design the fabrication area for both plastic and metal parts. Select fabrication equipment and tooling. Determine recurring and non-recurring costs, including maintenance. Provide a detailed layout of the fabrication area. Determine fabrication staffing by skill type and shift.
IE 4513 Engineering Administration Department of Industrial Engineering	Design the organizational structure for the venture, including all indirect labor and management staffing. Determine the annual cost of salaries, wages, and benefits for all employees.
ME 4443 Mechanical Systems Design Department of Mechanical Engineering	Analyze products for potential mechanical redesign considering such aspects as manufacturability, function identification, loading, consumer safety, marketing, reliability, performance, and cost versus value. See Smyer, et al.[3] for further discussion of this collaboration.
BIS 4753 Structured Systems Analysis and Design Department of Management & Information Systems College of Business & Industry	Design a management information system for a service industry operation. Provide a detailed cost estimate of installing, operating and maintaining the system, both software and hardware.

The Manufacturing Processes Collaboration

The Design of Industrial Systems collaboration with the Manufacturing Processes class is the most intensive and successful of the collaborations. Reasons for this are the common laboratory period on Thursdays, a realization by all Manufacturing Processes students that someday they will be enrolled in Design of Industrial Systems (the only collaboration for which this is true), the early involvement of the Manufacturing Processes teams in Design of Industrial Systems team activities, and the enthusiasm of the Manufacturing Processes instructor, who has extensive industrial experience.

The Collaboration Schedule

Figure 2 gives the schedule for the Design of Industrial Systems/Manufacturing Processes collaboration. The duration of nine weeks is the longest of any of the Design of Industrial Systems collaborations.

Figure 2. Design of Industrial Systems/Manufacturing Processes Collaboration Schedule.

	Semester Week								
Activity	3	4	5	6	7	8	9	10	11
Joint DIS/MP product teardown									
Statement of work from DIS to MP									
DIS/MP process analysis meetings									
Fabrication preliminary design									
MP interim report due to DIS									
DIS/MP interim design review									
MP design oral presentations									
MP final design review with DIS									
DIS evaluation of MP teams									

Product Teardown

In week 3, each Design of Industrial Systems team and its Manufacturing Processes team meet during a joint laboratory period for disassembly of the manufactured product selected for analysis by the Design of Industrial Systems team. The Design of Industrial Systems teams must purchase two units of the product, one for disassembly and another for various purposes, including field testing by the mechanical engineering collaborative team.

The product typically is a consumer item with a retail price of $30 to $60, and often consists of more plastic parts than metal. Thus the Manufacturing Processes design usually includes injection molding machines. Past products include an electric leaf blower, humidifier, electronic dart board, juice extractor, tricycle, adjustable height basketball goal, and trolling motor.

During teardown all component items are numbered, photographed and labeled. Tentative “make or buy” decisions are made at this time, with oversight and input from both course instructors. At this early stage in the semester, it is important to involve the Manufacturing Processes students in the teardown. This is well accomplished by requiring the Manufacturing Processes team to perform the actual disassembly of the product, with assistance as needed by the Design of Industrial Systems team. The teardown session is videotaped to assist later the Design of Industrial Systems methods analyst in determining assembly tasks.

The Design of Industrial Systems Liaison to the Manufacturing Processes Team

One member of each Design of Industrial Systems team is tasked with serving as the liaison to the Design of Industrial Systems team's Manufacturing Processes support team. The liaison role has evolved such that now the liaison is more of an Manufacturing Processes team leader or chair than a liaison. The Manufacturing Processes liaison is charged with chairing weekly (or more frequent) meetings of the Manufacturing Processes team to assist the team in discharging its subcontractor obligations. An effective Manufacturing Processes liaison becomes a champion of the Manufacturing Processes team as the work progresses. An ineffective liaison develops no pride of ownership in the Manufacturing Processes team's design.

The Manufacturing Processes liaison plays a key role in helping the Manufacturing Processes team get started. For many students the Manufacturing Processes project is their first experience with "open ended" projects and they struggle with how to get started. Because the Manufacturing Processes liaisons have successfully completed Manufacturing Processes projects, they can draw upon their experiences to provide "senior" leadership to the "junior" Manufacturing Processes team.

Statement of Work from Design of Industrial Systems to Manufacturing Processes

The Manufacturing Processes Liaison delivers a Statement of Work (SOW) to the Manufacturing Processes team early in week 4. It includes a fabricated parts list in Excel format, the product structure, estimated production volume for each year (years 1-5), the seasonality of production, and photos of each make part. The SOW requests an interim fabrication design report by the end of week 8.

Manufacturing Processes Interim Design

From week 3 through week 8, each Manufacturing Processes team researches various fabrication processes, identifies the raw material needed for each fabricated part, and designs the fabrication area to produce all parts in sufficient quantities to meet the Design of Industrial Systems team assembly line demands. Both the Design of Industrial Systems Manufacturing Processes liaison and the Manufacturing Processes class instructor serve as resources to the team. Investigation of raw materials is typically performed through product weighing, burn and smell tests. Investigation of fabrications methods is accomplished in large part through plant trips.

The Manufacturing Processes interim design includes the following items:

1. The fabrication direct labor content by machine, shift, skill level, and year.
2. Maintenance personnel by shift and year for the fabrication area.
3. The number of shifts each fabrication machine will operate by year.
4. Utilization factors for each machine by shift and year.
5. Batch size strategy (daily, weekly, etc.) per machine.
6. Machine cycle times/production rates.
7. Raw material specification for each fabricated part
8. Material handling requirements within the fabrication area.
9. Assumptions made in the fabrication area design.

Interim Design Review

One week after the Manufacturing Processes team produces its interim report, the entire Design of Industrial Systems team meets with its Manufacturing Processes team to review the interim fabrication design. The Manufacturing Processes liaison chairs this informal meeting. The Design of Industrial Systems team may suggest design changes. The Manufacturing Processes team entertains suggested changes from Design of Industrial Systems and attempts to incorporate them.

This provides the Manufacturing Processes team with the opportunity to receive feedback from a fresh set of eyes. The Manufacturing Processes team is encouraged to not be defensive about their design, but to show how to receive positive feedback. The senior design team is provided an opportunity to provide feedback in a constructive manner. It has been our experience that almost always the design review results in significant improvements in the overall Manufacturing Processes design (e.g., less fabrication labor).

The Design of Industrial Systems team provides to the Manufacturing Processes instructor an evaluation of the Manufacturing Processes team's performance on the interim design. The evaluation form is similar to the final report evaluation form shown in Figure 3.

The Manufacturing Processes team as a subcontractor is expected to track and manage all team action items so that nothing falls through the cracks in terms of which team and which person on that team has responsibility.

The Manufacturing Processes team is required to give a weekly 15 minute briefing to the Manufacturing Processes instructor and the Design of Industrial Systems team's Manufacturing Processes liaison.

Final Manufacturing Processes Design

The final Manufacturing Processes design is presented in week 11 through an oral presentation to the Manufacturing Processes class and the affected Design of Industrial Systems team. A design review follows immediately, primarily for error correction, if any. The final Manufacturing Processes design transmission includes:

1. The same deliverables as in the interim report, even if unchanged.
2. Equipment descriptions (functions) and specifications (size, type, number).
3. Equipment non-recurring (initial) costs for each of the five years.
4. Fabrication routing for each part.
5. Estimated scrap rates for each process.
6. Maintenance costs per year
7. Machine tool costs per year, with tool cycles.
8. Energy requirements and cost per year, including use (KWH) and demand (KW).
9. Total cost per year, separated into capital costs and expenses.
10. Block diagram of the fabrication area.

The client (Design of Industrial Systems team) may accept or reject the recommendations of the consultant (Manufacturing Processes). The Design of Industrial Systems team is aware, however, that the design of the fabrication area is not optional; it must be completed by the Design of Industrial Systems team if the Manufacturing Processes team's design is rejected. This motivates the Design of

Industrial Systems team, especially the Manufacturing Processes liaison, to assist Manufacturing Processes in developing an acceptable final design of the fabrication area.

The senior design team typically invites members of the Manufacturing Processes project team to the senior team's final oral presentation. The Manufacturing Processes team participant's involvement is dependent on the desires of the senior team. In many cases the Manufacturing Processes participant has a formal part of the design presentation and is always available to answer questions from the panel of industry judges.

Manufacturing Processes Team Evaluation by Design of Industrial Systems Team

Following the final design review, each Design of Industrial Systems team submits to the Manufacturing Processes instructor an evaluation of its Manufacturing Processes team's performance for the semester. This becomes a factor in the Manufacturing Processes team's project grade. The evaluation form is given in Figure 3.

Collaboration Lessons Learned: Students

- Encourages openness and opportunity to give and receive positive feedback.
- Appreciate the value of a fresh perspective (interim design review)
- Recognize that it is not the DIS team versus the MP team, but both teams against the problem.
- Opportunity to practice effective meeting management and facilitation.
- How to influence people's behaviors in cases where you do not have direct control.
- Dealing with customers where the supplier does not agree with the customer's position.
- Practicing good principles of project management: developing and managing using an action plan.

Collaboration Lessons Learned: Faculty

- Collaborations are valuable educational experiences.
- Statements of work should be developed with collaborative instructor involvement.
- Statements of work should incorporate all DIS requirements and collaborative instructor objectives.
- Tasks subcontracted must contribute to the educational goals of the collaborative course.
- Collaborative teams should have their hands on the product.
- Require interim designs, then reviews, then final designs -- iterate to improve the designs.
- Student liaisons to collaborative teams must be coached. The liaison is a resource, not an autocrat.
- There must be no surprises organizationally; deliverables and due dates must be widely known.
- Every collaboration meeting requires a leader who takes charge and works the agenda.
- Collaborative instructors must be given elbow room to prevent or minimize turf issues.
- Instructors must communicate often, and instructors must be active.
- Students should provide feedback at the end of the semester about ways to improve the collaboration.
- Much instructional effort and coordination are required.

Conclusion

Collaboration of project teams between courses requires much instructor and student effort, but results in a valuable educational experience for students preparing to enter the professional work force. The additional effort required by instructors for a successful collaboration should be recognized when by academic administrators.

Figure 3. Manufacturing Processes Team Evaluation by DIS Team

Manufacturing Processes Final Report Evaluation

Project Team: ______________________

Please evaluate the quality of the **final report** provided to you by the Manufacturing Processes design team. Rate on a scale of 1 to 5 each of the questions listed below.

Please use the following as a guide to your ratings.
1 – Poor
2 – OK, but needs improvement
3 – OK
4 – Good
5 – Excellent

1. Did the final report meet the objectives provided during the statement of work?

   1 2 3 4 5

2. Was the analysis provided thorough and accurate?

   1 2 3 4 5

3. Was the team open to suggestions and ideas for improvement?

   1 2 3 4 5

4. Was the report well organized and easy to understand?

   1 2 3 4 5

Please feel free to provide any other thoughts concerning the performance of the MP team.

Thanks for your help!

References

1. Senge, Peter (1990) *The Fifth Discipline: The Art and Practice of the Learning Organization*, Doubleday, New York.

2. Tompkins, James A., et al. (2002) *Facilities Planning*, third edition, John Wiley & Sons, New York.

3. Smyer, William N., et al. (2001) "IE Capstone Design Course with IE and ME Team Collaboration," *Proceedings of the 2001 ASEE Annual Conference*, ASEE, Albuquerque, NM.

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