THE USE OF INTRA-DISCIPLINARY DESIGN TEAMS FOR COMPREHENSIVE DESIGN PROJECT DEVELOPMENT

John Mirth, Ph.D. and Michael Momot, Ph.D.

Department of Mechanical and Industrial Engineering
University of Wisconsin – Platteville
Platteville, WI 53818

ABSTRACT

This paper reviews initial efforts undertaken within the Mechanical Engineering Program at the University of Wisconsin-Platteville to provide students with a more comprehensive and real-world exposure to design projects and project management. The efforts reviewed focus on the coordination of design projects between various combinations of Mechanical Engineering courses. Four trials have been performed where groups from different courses work together in the design, development, and construction of a single design project. This collaboration allows for the assignment of more comprehensive design projects while forcing students to work with and rely upon the expertise of others to realize a final product. Observations indicate many factors contribute to the success of the project, and that these tend to be the same factors that contribute to the success of a corporate project. These factors include the ability to establish a definite project management structure, the necessity for each group to rely upon the expertise of their pairing group for some portion of the project, and the need for good inter-team cooperation and communication. Obstacles to successful project development in this setting include the ability of students to coordinate meeting times, coordination of class project schedules between different courses, and the novelty of students having to rely on outside assistance to complete a project. The concept of intra-disciplinary project coordination shows promise for allowing students to participate in and complete more complex design projects that involve real-world project management issues.

I) INTRODUCTION

The introduction of the new EAC/ABET2000 accreditation system for engineering programs has produced a greater freedom for engineering departments to modify their curriculums to focus on the "soft" or less technical issues that are often associated with the engineering process. Indeed, some of these changes reflect a corporate movement towards concurrent engineering that hitherto has not been experienced in academic institutions. Unfortunately, the changes required from corporate culture and ABET have not resulted in sweeping alterations in curriculums. Some barriers that exist to curriculum change include the transition between old and new curriculums, consideration of transfer students, the need for faculty to redesign or even drop long existing courses, and thinking about the curriculum in terms of course pairings as well as a sequence. For these reasons, response to the new ABET criteria is more likely to occur in a stepwise manner than as a countrywide revolution in engineering education.

The purpose of this paper is to present a viable first step whereby an engineering curriculum can build bridges between existing courses to give students a more comprehensive experience with the soft issues of engineering education. The bridges are built through the incorporation of intra-disciplinary design projects.

The intra-disciplinary design projects presented in this paper involve the collaboration of two independent, upper division, engineering courses on a single design project. These projects are pursued to realize several results. Firstly, the projects are designed to develop a collaborative project environment where students have to rely upon the contributions of others to achieve an end result. This environment produces project management scenarios that cannot be easily developed within a single course. Secondly, collaborative projects allow for the development of more complete and comprehensive projects. Thirdly, the projects require the use of communication and team-working skills that the students would otherwise not be required to develop. Finally, the use of collaborative projects has the potential to enhance the student design experience while reducing the overall burden of design projects.

Intra-disciplinary projects have great potential benefits, but they also pose a number of challenges. The following sections will present some of the benefits and challenges that have been encountered in the use of these projects within the Mechanical Engineering Program at the University of Wisconsin – Platteville (UWP). The following sections will first look at the selection of coordinating courses and how to define an appropriate project. Implementation issues such as course coordination and interactions between both faculty and students will be examined next. Finally, a study of the different interactions pursued at UWP will be examined with an evaluation of the successes and failures that have occurred along the way.

II) SELECTION OF COORDINATING COURSES AND A PROJECT

The first step in setting up an intra-disciplinary design project is the selection of an appropriate set of courses to collaborate upon the project. The selection of proper courses and the project responsibility of each course have a large impact on the success of the collaboration. The following subsections describe the rationale for course selection and project selection.

A) Course Selection Considerations

To date, collaborations within the Mechanical Engineering Program at UWP have been limited to various combinations of two-course collaborations. These, along with a short description of primary course topics, are shown in Table 1.

Table 1: Collaborative projects undertaken.

Collaboration	Courses	Course Topics	Collaborative Project
1	Mechanical Systems Design	Design process and management, interfaces in system development	Autonomous mail carrier to deliver mail between two offices
	Mechatronics	Autonomous control primarily using microprocessors	
2	Mechanical Systems Design	Design process and management, interfaces in system development	Design and construction of an artificial hand
	Computer-Aided Engineering	Solid modeling, computer analysis of engineering problems, software integration	
3	Theory of Machines	Design and analysis of machines such as linkages, cams, gears	Design and construction of a golf ball launching device
	Computer-Aided Engineering	Solid modeling, computer analysis of engineering problems, software integration	
4	Mechanical Systems Design	Design process and management, interfaces in system development	Design and construction of an electronic *Etch-A-Sketch*®
	Automatic Controls	Autonomous control primarily using analog circuitry	

The courses listed in Table 1 have several common characteristics. Firstly, they are all upper division courses. Secondly, they are all from the "mechanical stem" of mechanical engineering. And, finally, all of the courses traditionally have a design project included within the course presentation.

The use of upper division courses was employed primarily for two reasons: juniors and seniors are more likely to know one another and they have also attained a certain degree of technical expertise. Courses at a common level in the curriculum should be used in forming collaborations so that there is a better potential for student interaction as a result of familiarity and common schedules. Additionally, the project helps tie the curriculum together and allows students the opportunity to see how different aspects of their education will be used. Note that these are some of the advantages that intra-disciplinary projects have over inter-disciplinary projects.

The courses have been limited to the mechanical stem principally because the participating faculty are from these areas. The similarity of courses perhaps has the advantage of being able to more clearly define the interface issues and boundaries of each class' contribution. Using the expertise of the energy stem could be fairly easily done, however. For example, the control circuits for one project would fail after a period of time, simply because they became too hot. If a course in heat transfer had been incorporated into the project, the students could have easily analyzed and designed a more efficient cooling scheme.

The prior existence of a design project in each course is also beneficial. The goal of the implementation is to smoothly integrate the combined project into each course. This is much more easily done if the course has a pre-existing requisite project.

B) Project Selection Considerations

One of the biggest challenges in developing an intra-disciplinary project is the selection of the project itself. The first mandate in project selection is that students must be required to produce something more than a paper design. In our case, the project has always required a deliverable prototype. Selection of an appropriate project must also include consideration of the capabilities and limits of each course to contribute to the project, project expense, and timelines.

A deliverable prototype has been a central part of all the intra-disciplinary projects undertaken by the authors. Part of the goal of the projects is to produce a more realistic project management environment for the students. The reality of ordering and assembling parts and coordinating this between two contributing groups goes a long way towards achieving this goal!

The ability of each course to contribute to the project may be one of the biggest factors tied to the success or failure of the collaboration. Some of the fundamental guidelines that we have developed for project selection include:

1) The project should require a significant and well-defined contribution from each course.
2) The courses should be able to do a substantial amount of independent work on their contribution.
3) The project should contain possibilities for the courses to work together to define interfaces between the different course contributions.
4) The required contribution of each course should be such that it dissuades students from crossing over between courses (unless they are enrolled in both courses). This reduces the possibility of students from one course from taking over the entire project.
5) Each course should be able to contribute project groups of a manageable size (4-6 students per course seem to work best).

Note that a project that has a modular architecture as opposed to an integrated architecture solves a lot of problems. Separate chunks of the project may be assigned to different courses, with a well-defined interface between the chunks set-up at the beginning of the project. For example, in some of the collaborations, the control circuitry was defined as one chunk with the mechanism defined as another, and a cable was used as the interface.

Finally, project expenses and timelines must fit in with the available resources. All projects considered here have been accomplished within a single semester. Although project management techniques have not been used to a great extent, their advantages are easily seen. A Gantt chart, for instance, would allow the student "project managers" and faculty to see the progress of the project. This might help alleviate the end of semester push that so many projects exhibit.

Course and project selection play a major role in the success of the collaboration. The next section considers a number of related implementation issues. The primary focus of the next section is on interactions among the teaching faculty and interactions among the student teams.

III) IMPLEMENTATION ISSUES

The actual implementation of intra-disciplinary projects provides a number of new challenges for both the coordinating faculty and the student teams. Indeed, a substantial motivator for these projects is to challenge the project management skills of the students. As an added "bonus," these projects also tend to challenge the project management skills of the faculty! This section looks at some of the coordination issues that may have to be addressed during the course of an intra-disciplinary design project. From the student perspective, these include communication between groups, scheduling meetings, and defining areas of responsibility. For faculty, management issues to be addressed include coordination of course material with project checkpoints, deadlines, and faculty communication. Both student and faculty related implementation issues are addressed in the following sections.

A) Student Related Implementation Issues

The ultimate goal of intra-disciplinary design projects is to enable students to effectively coordinate and work within projects that require contributions from independent teams. However, part of the process involves assisting students and providing guidance and suggestions to lead them to this final objective. Areas of useful guidance include the definition of team responsibilities, ensuring communication lines are setup, and defining common meeting time.

The intra-disciplinary projects are realized through project teams from each of two different courses collaborating on a single design project. The first hurdle in this collaboration is to define the responsibilities of each team. A properly chosen project will have some obvious areas of concentration for each course. An example is a mechanical system operated by an electronic control system. A course that focuses on machines, mechanisms, or mechanical design would assume the responsibility for the design and construction of the mechanical parts. A course that focuses on controls or mechatronics would assume the responsibility for the controls. Once these lines are drawn, some "gray areas" also exist. These include the responsibility for the design of the interface between the two subsystems, and the responsibility for the design of items that may not fall under the topics of either course. The guiding faculty members must be aware of these gray areas and make sure that teams are recognizing these areas and assuming responsibility for their completion.

A second hurdle in the collaboration process is the establishment of effective communication between the teams from the different classes. Several possible methods exist to handle this, as shown in Figure 1. These include:

(a) Total Group Meetings. Defining large group meeting times where both groups come together. This may be the least efficient method for communication, as it requires a large group of students (maybe 8-15) to coordinate their schedules to find a common time block. Also, large group interactions are not as effective as smaller group interactions.
(b) Small Group Interaction -- using students who are enrolled in both courses as a go-between. At the upper division level, chances are fairly high that one or more students will be enrolled in both courses, unless one course is a prerequisite for the other. This situation ensures that both groups are in contact. Several potential downsides to this include the fact that not all groups may contain such a person. Communication between teachers can alleviate this problem. Also, groups that contain more than one such person may tend to have these people "take over" the project. A natural tendency is to give such people greater project leadership responsibility. The better case, however, is to give such people communications responsibility but to not assign them to overall leadership to ensure a more even distribution of workload.
(c) Individual Liaisons. These people are ones who are only enrolled in one of the courses, but have frequent contact with the collaborating course group. The interaction in this case may come from the liaison sitting in on the group meetings for the other course, or perhaps just having the liaisons themselves arrange a personal meeting time.

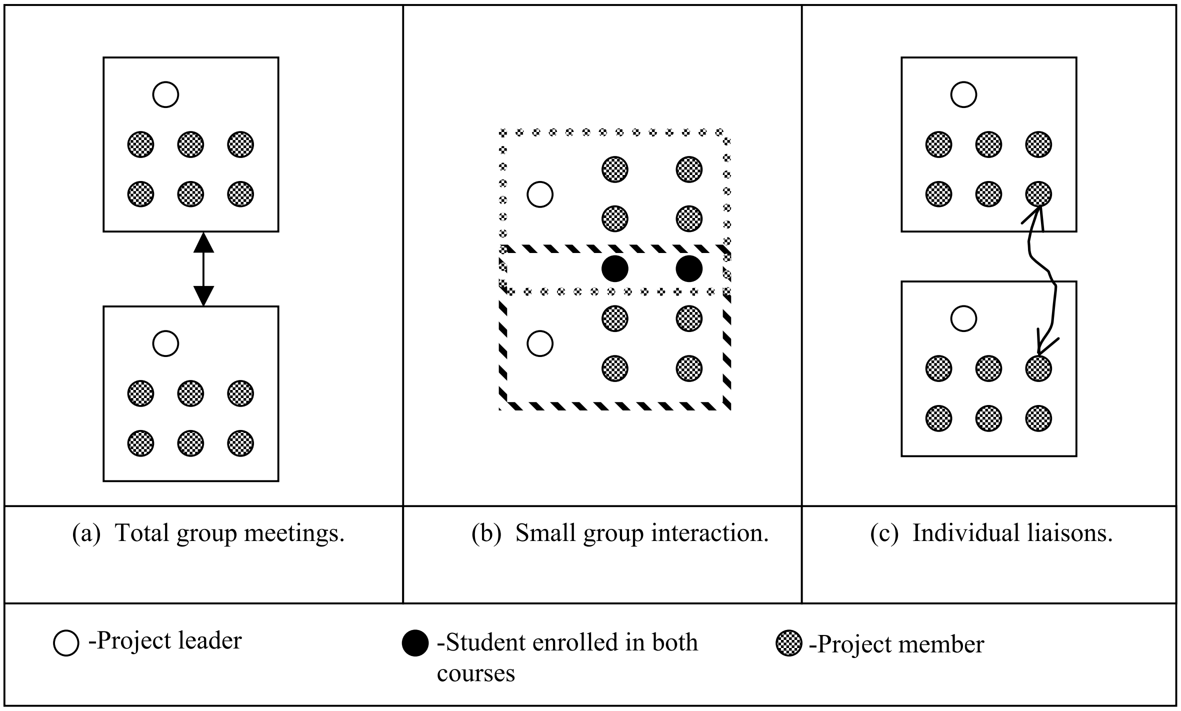

Figure 1. Communication schemes between groups.

Other communication schemes are also possible, including email and data exchange through computer databases. The use of a shared directory has been used to exchange documents, including a bill-of-materials, AutoCAD and Inventor drawings, and reports. These have proven to be invaluable, as the directory allows students to work at different parts of campus or at different times and obtain necessary information as needed. Just as in industry, care must be taken in establishing the directories so that the students maintain the current revision in the root directory, and older revisions in a sub-directory. Also, directory protection is a good idea so that other courses cannot sabotage a project. A bulletin board system has not yet been used, but its implementation could also prove advantageous.

Regardless of the communication scheme adopted, both collaborating teams need to be aware of the progress and requirements of the other team. This is not always a given, as in one instance where liaisons who lived in the same house failed miserably to communicate with one another.

Another factor is shared project space. Depending on project size, this could be a locker, a cupboard in a lab, or space in the workshop. The space should be accessible to students at all times, especially since they are fond of working late at night, and the students should realize that it is a shared project. Occasionally, a complaint has been registered that one student has taken the project home in order to work on it, and that other students were not able to access the project.

A final issue for students to address is group meeting time. The nature of the collaboration requires some investment in project management during these times. Once again, student schedules may not make for readily available meeting times outside of class. As such, the arrangement and use of specific class periods throughout the semester may be the best method for providing at least a minimal amount of meeting time. This allocation of class time also allows the supervising faculty the opportunity to interact with individual groups.

B) Faculty Implementation Issues

Just as the student teams need to work together, the coordinating faculty also need to have good communication to ensure a positive outcome. This communication is reflected in course development, and awareness of project deadlines.

Perhaps the most difficult issue with coordinating faculty is fitting a collaborative project into a course schedule. Design projects typically come due at the end of the semester. One reason for this is that most of a semester is required to present students with sufficient information and expertise to complete any particular design project. Unfortunately, collaborative projects often run into the problem where one team requires use of the other team's final product somewhat before the end of the semester. Even more common is the possibility that teams will need midterm information and design concepts from each other. However, these exchanges cannot take place unless the overseeing faculty have arranged a course schedule that delivers information to students within the necessary time frame. This requires the faculty to work with each other to arrange their presentation of material. This may even require creating courses in a modular format where information can be presented on a "just in time" basis for those courses where students are given greater freedom to define their own due dates and checkpoints.

Project deadlines may also become an issue, particularly if a particular deadline is allowed to slide. Collaborative projects require a greater discipline on the part of faculty to maintain pace with the course schedule so that the students have sufficient time and opportunity to exchange information and meet deadlines. The use of a Gantt chart, as shown in Figure 2, allows the schedule and its implications to be communicated to everyone in an efficient manner.

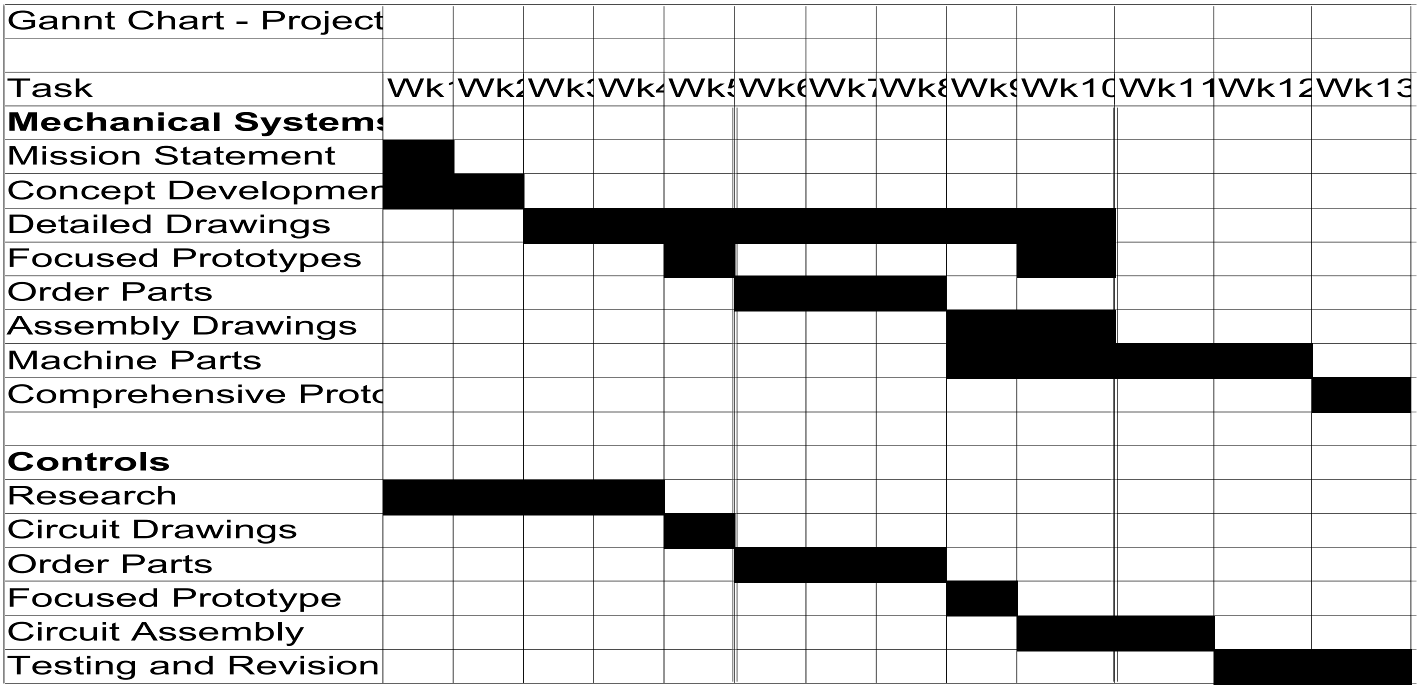

Figure 2. Sample Gantt chart made using Microsoft's Excel.

IV) SUCCESSES AND FAILURES

Over the past two years, intra-disciplinary projects have been introduced on four different occasions within the Mechanical Engineering Program at the University of Wisconsin – Platteville. These projects have, by and large, been successful. However, they have also produced some failures, which form much of the basis for the potential project difficulties presented in the previous sections. This section specifically discusses the different collaborations and their successes and failures.

Collaboration #1: Automated Mail Carrier – Mechatronics with Mechanical Systems Design.

The first collaboration undertaken was the development of an automated mail carrier to deliver mail between the Mechanical and Industrial Engineering offices at UWP. The design was to be an autonomous vehicle capable of traveling out the door of one office, down a long hall with several turns, and into the door of a second office.

This collaboration was quite successful. Particular strong points include the fact that the mechanical and control systems were distinctly separated so that each course had a fairly well defined design responsibility. In addition, the interface issues of the two systems (such as who decides what motor to use) were complex enough to require the students to consider project management responsibilities.

Perhaps the most glaring weakness of this collaboration was the existence of students who were enrolled in both courses. Each design team contained one or two such students. At least one design team was driven by these shared students at the expense of excluding several of the students who were only enrolled in one course. A second design team relied too heavily on its dually enrolled student and when that student was absent the communication lines between the courses were severed.

Collaboration #2: Artificial Hand – Computer-Aided Engineering with Mechanical Systems Design.

The second collaboration involved the development of a single degree-of-freedom (one actuator) artificial hand. The Computer-Aided Engineering (CAE) course was responsible for using computer analysis and simulations to develop the geometry of the fingers, while the Mechanical Systems Design (MSD) groups were responsible for problem definition and design construction.

This was another largely successful collaboration as the roles of the courses were distinctly defined. The MSD course played the role of product developer while the CAE course students served as subcontractors to the MSD course. The geometry development of the fingers forced the MSD students to rely entirely upon the CAE students' models and simulations for these designs. This proved to be a good exercise in communicating design requirements between groups. The initial design requirements developed by all of the MSD teams turned out to be impossible for the CAE teams to meet. Back and forth negotiations were used to resolve these differences and drive the design to one that was achievable by the CAE students and acceptable to the MSD students. The use of focused prototypes also proved valuable in helping the MSD students confirm the finger designs produced by the CAE students.

Collaboration #3: Golf Ball Launcher – Computer-Aided Engineering with Theory of Machines.

A third collaboration involved the development of a cam-actuated linkage that would toss golf balls into a specified target receptacle. The CAE class was responsible for providing computer-aided solutions for the cam design and for developing a computer model of the design. The Theory of Machines teams were responsible for using the CAE class' guidance in developing the final cam and linkage designs.

This collaboration was a dismal failure. The primary problem that arose was that the two courses were not sufficiently interdependent upon one another. The Theory of Machines teams were capable of completing a fully functional design without requiring any consultation with the CAE teams. The only group that made effective use of the collaboration was the one group that had two members that were enrolled in both courses.

Collaboration #4: An Electronic Etch-A-Sketch – Automatic Controls with Mechanical Systems Design.

The mission of this project was to develop a device that used pens, pencils and markers to write on a piece of paper in a manner similar to an *Etch-A-Sketch*. The Mechanical Systems Design course was required to design the packaging, the pen carriage and the drive, while the Automatic Controls course was required to design a feedback system to control the horizontal and vertical position of the pen. The collaboration worked fairly well, with all four projects in good working order by the end of the semester. The major problem in this scenario was that the controls group had to wait until late in the project to implement their circuitry, and did not have much time to do a dynamic model of the system. Also, the controllers proved to be straight-forward with very little design effort.

The main problem lay in the fact that the project was executed in a sequential fashion, without any thought to concurrent engineering. By the time the controls group was able to test their circuitry, the packaging, drive, and carriage design had been "set in stone." Mechanical problems, such as a high degree of friction, could not be overcome simply using feedback, yet the mechanical design team was of the opinion that it was the control teams' problem after a certain point.

V) CONCLUSIONS AND RECOMMENDATIONS

The use of intra-disciplinary design projects has been done with some degree of success at UWP. For the most part, the projects have achieved their goal of presenting students with more challenging project management issues than can be addressed within a single course project. For future projects, the key issues to be considered are:

- Communications between groups and faculty
- Shared space for projects
- Scheduling
- Costs
- Project determination
- Group structure

Once a good model is determined considering the schedule, communications, group structure and storage, the main consideration is project selection. The other considerations may stay relatively the same from year to year, but the project description should vary to accommodate critical thinking. Choosing a good project that can be divided into well-defined chunks applicable to two (or more) courses is the single most important aspect of intra-disciplinary projects.

Intra-disciplinary projects are more representative of industry and the push towards concurrent engineering. The projects have also enabled students to participate in more comprehensive projects without significant changes in the time requirements to complete the projects. Finally, the projects have allowed us to explore some of the possibilities associated with the more flexible ABET guidelines without requiring a complete restructuring of the curriculum. On one hand, the projects have presented us with valuable insight that may one day help us in a curriculum restructuring. On the other hand, the projects have been successful enough on their own to indicate that the traditional engineering curriculum can also be put to effective use to pursue some of the less technical skills demanded from today's graduating engineers.