DESIGN PROJECTS THAT EMPHASIZE TECHNICAL COMMUNICATION BETWEEN ENGINEERING AND TECHNOLOGY STUDENTS

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ABSTRACT

This paper summarizes ten years of effort at Purdue University to improve the technical communication skills of engineering and technology students. While there are many forms of communication that must be mastered by engineers and technologists, the preparation and interpretation of technical drawings and associated process documentation is essential for design concepts to be successfully transferred to actual products. It is also essential that students be able to function effectively in cross-disciplinary teams. With these needs in mind, the authors have experimented with several types of cross-class projects that require engineering students from the School of Aeronautics and Astronautics to communicate technically with students in the Department of Aviation Technology. These projects generally entail preparation of a structural design by engineering students that is then conveyed through formal drawings in a manner that results in hardware constructed by the technology students. The various projects have involved several different course interactions at the sophomore, junior, and senior level in the two separate academic units.

1. INTRODUCTION

The success of an engineering design requires accurate transformation of the concept into a final manufactured part. The most common media for transferring design information to manufacturing personnel is in the form of technical drawings. The drawings must accurately describe the design in order to successfully produce the final product. In a recent survey at The General Electric Company, however, it was reported that 60 percent of all manufactured components are not made exactly as represented in the drawings (Ullman, 1997). The reasons for this discrepancy include:

- Incomplete drawings
- The components cannot be manufactured as specified

- The drawings are ambiguous
- The components cannot be assembled if manufactured as drawn.

Although engineering students in the School of Aeronautics and Astronautics study solid modelling and drafting as freshman, subsequent required courses do not routinely entail preparing drawings that lead to manufacture of actual hardware. Thus, students have limited opportunities to develop the skills to address the above deficiencies encountered in industry.

Modern industrial management systems have also found that multi-disciplinary project teams provide synergism that leads to lower costs, improved quality, better delivery performance, and better overall customer satisfaction (Groover, 1996). In addition to promoting more pride of ownership by the employee, significant improvements in the development process occur when all project disciplines are included during the planning stages. While team projects are common in engineering and technology classes, course prerequisites often lead to homogeneous teams that limit interactions between students with significantly different backgrounds and career goals. Thus, it is difficult for a single class to simulate teams with the broad technical diversity encountered industry.

It was decided to address both of the issues described above through cross-class projects conducted with the Department of Aviation Technology and the separate School of Aeronautics and Astronautics. As discussed below, three different course combinations have been examined to date, including projects conducted with sophomore, junior, and senior students. It should be emphasized that these are not combined classes. They are, rather, independent engineering and technology courses that have different educational goals and content, but which collaborate on a common design-build-test type project.

2. SOPHOMORE CLASS INTERACTIONS

The sophomore experience involved an introductory strength of materials course in the School of Aeronautics and Astronautics (AAE 204, Aeromechanics II) where engineering students designed a simple component subjected to a variety of specified constraints. They submitted Computer Aided Design (CAD) drawings to a junior class in Aviation Technology (AT 308, Aircraft Materials Processes). The technology students created "virtual parts" from the CAD drawings using the Computer Aided Manufacturing (CAM) software program SurfCAM that would run Computer Numerically Controlled (CNC) manufacturing equipment.

AAE 204 is a required second year course that gives the opportunity to involve a large number of students in the project. The AT 308 class is a junior level course focusing on the manufacturing and repair of aircraft structures and provides exposure to practices and processes typically used in the aviation industry. The AT 308 students have the background to read and apply the technical drawings produced by the engineering students. Since the AAE 204 and AT 308 class sizes usually differ, it is necessary to team students within a given class to have the appropriate number of projects.

The AAE 204 teams were required to analyze a simple torsion shaft using strength of materials concepts developed in class, and to design the minimum weight structure that met several specified criteria. A general introduction was given to AAE 204 students who were allowed to form teams of 3-4 students. These teams had 3 weeks to complete the design and prepare formal manufacturing documents. Each team submitted a technical drawing of the part with a title block and Bill of Materials (see Figure 1) to students in AT 308. Those students then produced "virtual parts" by programming the SurfCAM instructions needed to run the CNC tooling. Any missing data must have been requested and provided through formal written communication between the engineers and technologists. Although there was usually not enough time during the semester to produce actual hardware, that could have been a routine process once the CNC software was programmed and verified.

This cross-class experiment was conducted three times – during the spring and fall semesters of 2002 and the spring semester of 2003. The AAE 204 students submitted drawings with varying degrees of clarity and accuracy. Most groups produced legible and concise manufacturing documents, but some contained errors associated with dimensioning and tolerancing. Many of the groups did not consider the effect of drilling a bolthole with a plus/minus tolerance, for example, nor was consideration given to the fit of the bolt when the bolthole was drilled to the minus tolerance. Another common mistake was defining multiple dimensions and tolerances for a single dimension. Double dimensioning creates ambiguity in the drawing and does not clearly communicate the design.

Feedback from the AT 308 instructor was given to the AE 204 students at the end of the semester. A survey conducted with the AAE 204 class indicated positive student feedback for this project. They reported that the project increased their ability to communicate an engineering design and highlighted the need for clear and accurate drawings. Some students compared this project to experiences gained on co-op assignments. The positive response from students in both classes indicates the value of this project to their educational experience. Further details of this project are given by Rodrian (2003).

3. JUNIOR CLASS INTERACTIONS

Another experiment with intradepartmental communications involved a required junior class in aerospace structural analysis (AAE 352, Structural Analysis I) that again worked with the Aviation Technology AT 308 class. In this case, the technology students constructed a series of C-shaped channel sections using a drawing prepared by the course instructor. These channels were then riveted together along their length to produce a closed cell box beam (see Fig. 2). A series of AAE 352 homework assignments required the engineering students to analyze the geometric properties of the beams and to determine the minimum number of rivets and required spacing to prevent failure when loaded in three-point bending. As before, the AAE 352 students submitted formal drawings and specifications regarding the desired rivet pattern to the technicians. Once the beams were joined together, the two classes met together to load them to failure and to verify the calculations for the minimum number of rivets.

Although this was a fairly straight forward flexural shear stress analysis problem for the engineering students, and a routine manufacturing exercise for the technology class, the two groups were required to communicate their desires via formal shop drawings. This experience provided the opportunity to verify the soundness of their basic design and manufacturing quality through actual component tests. It made the respective homework assignments much more interesting for the two groups, and provided an industrial context for their work. Although initial communication between the two classes was limited to the formal drawings and associated documentation, both groups did meet together for the final proof testing. This project was conducted twice, during the 1997 and 2001 academic years, and was quite well received by both groups of students.

4. SENIOR CLASS INTERACTION

The most sophisticated cross-class interaction studied to date involves two elective senior courses (AAE 454, Design of Aerospace Structures and AT 408, Advanced Aircraft Manufacturing Processes) where engineering and technology students are teamed for a complex design-build-test project (see Figure 3). This semester long assignment has been conducted annually since 1995. Since this type of project has been described elsewhere (Grandt and Watkins, 1997, Grandt and Watkins, 2001), only a brief summary is given here.

The design-build-test project is chosen to be beyond the scope of either class individually, but within the combined skills of the two sets of students. The cross-class assignments entail designing, fabricating, and testing to failure a minimum weight and cost structure subject to several specified constraints. The authors form teams and issue a formal RFP by the end of the second week of the 16 week semester. The teams are given several weeks to prepare a formal design proposal that satisfies the given RFP requirements. This “design” consists of documented materials selection, stress analyses, preparation of engineering and assembly drawings, and development of production process sheets for all manufacturing activities. The teams are given a budget to purchase materials (typically \$100 – \$150) from a material supplier’s catalogue. This procedure defines the available materials and product forms that can be used for the project, and also forces consideration of both price and product availability.

Following acceptance of the proposal by the instructors (including revisions), materials are ordered and the teams build the components in the Aviation Technology machine shops. Labor rates are established for machine tools, and each team is required to record actual machine time, leading to another component of production cost. The final products are tested to destruction to determine the ultimate load capability and to identify “weak links” in the structure. The destructive test provides the opportunity to analyze the failure mode(s), and determines if the component was “over” or “under” designed. The teams then prepare a final report and presentation that assesses their design’s strengths and weaknesses, identifies components that needed additional strengthening, and discusses potential areas for weight savings.

The key differences between this project and the other two described previously include the increased complexity of the design problem and the fact that the two groups of students work together during the entire semester. During the initial design procedure, for example, the engineering and technology teams discuss the manufacturing feasibility of various approaches to the design problem (i.e., can the component be built with available equipment during the allotted time frame), rather than coming up with a design that is then “thrown over the wall” to the manufacturing unit. It is felt that the cross-class interactions described here provide experience with the types of technical communication required in today's workforce. The engineering and technology students have appreciably different backgrounds, and, in general, do not know each other before hand. The fact that the respective departments are located approximately one mile apart on campus inhibits casual meetings, and forces increased dependence on formal scheduling and documentation of team interactions.

5. CONCLUSIONS

The manufacturing exposure given by these cross-class projects benefit students in both departments. The engineering students have the unique experience of applying engineering theory at a sophomore - senior levels to develop a design and communicating the design to aviation technology students for manufacturing processing. Aviation technology students have the opportunity to work with designs produced by their engineering peers and had to identify discrepancies and errors in the design documents. These cross-class interactions simulate a degree of realism to the types of technical communications required in industry.

ACKNOWLEDGEMENTS

Professor W. A. Watkins died suddenly the day after the abstract for this paper was submitted to the 2005 IL/IN Sectional Conference. Discussion of this proposed paper was, in fact, the last communication between the authors, and that memory is especially treasured by A. F. Grandt, Jr. and J. E. Rodrian. We join Professor Watkins' former students and colleagues in mourning his untimely death, and will greatly miss his passionate efforts to provide meaningful collaborations between engineering and technology students. We dedicate this paper to the memory of his enthusiastic endeavours to simulate the multidisciplinary team interactions that are so important to the professional education of engineering and technology students.

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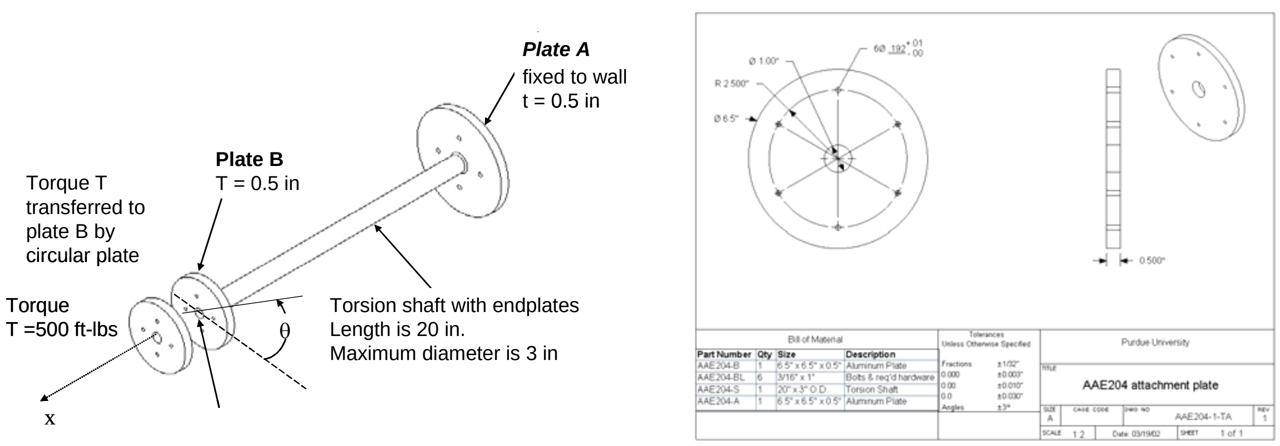

Figure 1: Torsion shaft design problem with typical drawing produced by engineering students and used by technology students to produce virtual parts with CNC software.

Two channels riveted together to form box beam

Sheared rivets after testing in 3-point bending

Figure 2: Drawing of channel cross section produced by technology students and then riveted together to form a box beam that is loaded in three-point bending to shear rivets.

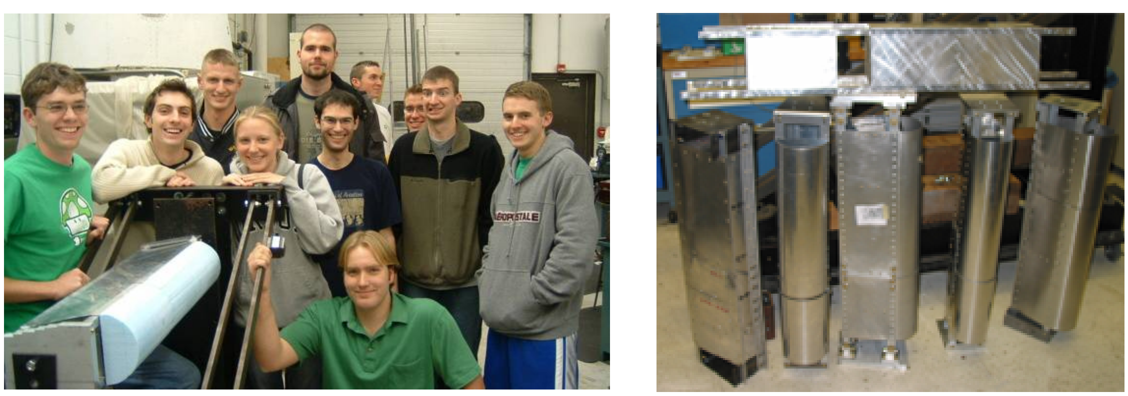

Figure 3: Typical AAE 454 and AT 406 design-build-test team and examples of thin-walled wing type structures built and tested to failure as cantilever beams (Fall 2004 semester).