Evaluation of an Industry Project in a Freshman Course

Nancy L. Denton, Jan Lugowski, Jody Knoll
Purdue University/Sun Microstamping

Abstract

A unique opportunity for mechanical engineering technology students to create engineering drawings for an existing product for a manufacturer arose in spring of 1999. In keeping with the engineering technology philosophy that students learn more through practical application of knowledge, the documentation project was undertaken.[1, 2]

The paper describes the content of a freshman-level design documentation course and the industry documentation project. Implications of incorporating a relatively comprehensive project into the existing course syllabus are discussed. An evaluation of the project's benefits and costs to student learning follows, together with suggestions for future improvements.

I. Background

The Mechanical Engineering Technology Department at Purdue University requires two courses in engineering documentation. The first course introduces fundamental visualization skills, drawing practices, and use of a two-dimensional and three-dimensional CAD software package. The second course, the focus of this paper, helps the student to understand and properly communicate specifications needed to produce a given part or assembly. Course topics, as listed in Table 1, cover critical design aspects such as calculation of fits and application of geometric dimensioning and tolerancing. Technical documentation and design support skills are developed to the extent that a successful student can produce or supervise the production of all documentation needed to manufacture a mechanical product upon completion of the course.

Course assignments consist of a number of small practice exercises and eleven projects. Traditionally, the projects have been independent entities, with the exception of a mechanical assembly package that undergoes two modification stages.

In December 1998, an Indiana company contacted the MET Department Head in search of students to develop the detail/assembly documentation for an existing, functional product. Photographs of the product suggested that the documentation project's scope might be realistic for completion within a one-semester three-credit course. The company was willing to work within the constraints of a standard semester timeframe. Course faculty agreed to undertake developing full design documentation for a cart-tipper as a student project integral to the second documentation course. A sample cart-tipper, the hydraulic unit that tips and compresses garbage in a typical sanitation truck, was subsequently sent to Purdue University to confirm project feasibility and let course planning begin.

II. Motivation

The Production Design and Specifications course has traditionally received strong praise from employers and alumni, while receiving strong criticism from current students ("Why do I need to know that?" "I'll never do this again," etc). The importance of many course topics is difficult to convey without applying the knowledge to a real product. [3-5]

The literature from many disciplines indicates that student learning is enhanced through application of theory to real problems. [6-10] Course faculty hypothesized that the experience of working hard to develop product documentation would be more satisfying if students knew that the result of their labor would satisfy a company need.[3-5, 7] Course projects would no longer simply be academic exercises, although the company could not use every student's work. In addition, the course instructors expected enhanced student confidence and skill in relating two-dimensional representations of objects to the three-dimensional world through repeated interaction between the orthographic representation and the actual part. Other anticipated benefits were faculty-industry cooperation and graduate student development opportunities.[7]

The cart-tipper further enabled the introduction of integral components and concepts of the MET curriculum in a manner that emphasized interrelationships rather than segregated niches. Affected subjects include the hydraulic cylinder for fluid power, welding from the first manufacturing processes course, machining from the second manufacturing processes course, reverse engineering (reinforcing design documentation course concepts), and some simple components from the machine elements course.[5]

III. Project Description

The cart-tipper, shown in Figure 1, is a hydraulic unit formed primarily by welding. It contains numerous standard components including fasteners and rod end bearings. A few fits are critical to its operation. Several sections appeared to be appropriate subassemblies, and were treated as such to facilitate drawing package completion. The actual unit was more complex than indicated by initial photographs, so some simplification was necessary in order to complete the project during one semester. The hydraulic cylinder subassembly was treated as a "black box" to eliminate one of the more difficult portions of the project, especially its disassembly.

Before the cart-tipper project was assigned, the issue of how to communicate necessary project information to the students without providing the orthographic drawings that the students were expected to generate had to be resolved. Our solution was to have a graduate teaching assistant measure the cart-tipper, then draw and dimension two-dimensional isometric drawings of its components. These drawings were placed on the course server as well as shown on the distributed paper copy of assignment directions. Digital photographs of the cart-tipper were loaded onto the course server to provide overnight and remote access to visual aids. Finally, the cart-tipper, dial calipers, and micrometer calipers were kept in the CAD laboratory to facilitate answers "from the source" whenever questions might arise.

Undergraduates, particularly freshmen, rarely possess the time management skills, organizational skills, and self-discipline needed to complete an extensive project without regular instructor intervention.[5,6] The intervention strategy we adopted was twofold. First, students were given weekly or bi-weekly project assignments containing portions (usually subassemblies) of the total drawing package throughout the semester, rather than the full project at one time. Each assignment contained recommended intermediate deadlines, objectives and rationale for that phase of the project, and incentives to keep students on the work schedule. Second, each short-term project assignment specified the approximate minimum amount of work to finish on a daily basis to keep the project on schedule. Although few students managed to meet the recommended schedule for the entire project, most were able to recognize when they were falling behind and took corrective action while it could be effective.

For the documentation package, students developed a complete set of orthographic detail drawings, subassemblies, and a final assembly using their choice of two-dimensional or three-dimensional solid AutoCAD® R14 software and various supplemental packages. The final drawing package consisted of twenty-one detail drawings, six subassemblies, numerous standard parts, and a final assembly.

IV. Integrating the Project Into the Existing Course

Production Design and Specifications is a well-established course with learning objectives developed by departmental faculty at seven locations and approved by the MET Curriculum Subcommittee. Any industry project undertaken must fit within the scope of the existing course. As shown in Table 1, the cart-tipper project encompassed the majority of the time and project points for the course. Given some lead-time, the two review assignments (industrial sketching and AutoCAD review) could have easily involved documentation of cart-tipper components. With additional preparation time, the casting for the hydraulic unit could have served as the casting conversion assignment. The cart-tipper facilitated repeated exposure to welding symbols, stock material, and fasteners, while flat pattern development was revisited. Renewed contact with course materials led to higher retention of these sometimes tedious subjects.

In order to ensure that sufficient practice with fits and GD&T remained in the course, some primarily academic modifications to the cart-tipper drawing package were made. To address these changes and to ensure consistent quality in the final documentation package, one of the two graduate teaching assistants in the course was hired on a one-week company contract to finish the documentation package. Working from two or three of the best sets of student work, the teaching assistant inserted the company title block, removed unnecessary GD&T features, and corrected the students' work as needed to develop the final documentation.

V. Project Benefits and Drawbacks

With any new academic endeavor, review of course outcomes to determine what new aspects should become standard in a course and which components should never occur again must follow the initial implementation. Tables 2 and 3 address the revisiting of the cart-tipper project and the instructors' assessment regarding its successes and limitations.

VI. Conclusions and Recommendations for Future Classes

Incorporating an industry project into this second-semester freshman course brought numerous enhancements to student learning and resulted in increased student satisfaction and confidence in their ability to perform at the level required for employment success. Instructors managed to incorporate the project into the course with minimal modification to the syllabus. Stronger, more obvious links between this design documentation course and other MET courses in manufacturing processes, fluid power, and materials were highlighted. In addition, the use of technology such as the digital camera and course server made incorporation of the project into the course much more feasible.

Enthusiasm and frustration vied for position as the leading emotion throughout the project. While the positive aspects of the project outweighed the negative, the work required for project completion was too much to be appropriate for a three-credit course. Similar future projects need to be scaled back so students have time to concentrate on what they are learning as well as completing their drawings. Sufficient lead time for completion of draft versions of the project by the instructors before the students begin work would eliminate confusion in the written and verbal directions provided, ensure that the scope of the assigned project tasks is realistic and reasonable for the class, and afford time for communication between the instructors and company to occur beforehand. In an ideal situation, the instructors could select an industry project that emphasizes the major course topics of fits and geometric dimensioning and tolerances while maintaining a relatively limited project scope.

Overall, the attempt to include an industry project into the design documentation course proved useful. Developing the documentation for a real product in a reverse engineering mode was repeated in the fall 1999 offering of the course, with modification to account for the changes recommended from the spring 1999 semester. The second project, documentation of a test fixture assembly for an MET laboratory, retained nearly all of the benefits of the cart-tipper project while eliminating most of its drawbacks. Full assessment of student learning is not yet available, but preliminary evaluations indicate that a much better balance was achieved between time spent "experiencing, and time spent "learning."

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Table 1: Course Topics and Projects

Course Topics	Assigned projects (Cart-tipper indicated in italics)
ANSI Y14.5M-1994 Dimensioning and Tolerancing rules (especially for holes)	Industrial Sketch (50 points)
Technical Drawing and AutoCAD review	Draw/dimension a given non-standard orthographic drawing on AutoCAD according to ANSI Y14.5M-1994 requirements
Casting drawings **Surface roughness and surface texture symbol**	Casting conversion from machine drawing file (100 points)
Weldments and welding symbols **Selection and specification of stock material (catalog use)**	*Weldment of cart-tipper top using stock material* (100 points)
Flat pattern developments (bending of sheet metal)	Flat pattern of a box and *cart-tipper slides* (125 points)
Fasteners and threaded holes **Exploded isometric assemblies**	Exploded isometric assembly (from solid components)
Soft and hard design conversions **Concurrent engineering** **Fits and Tolerances: ABC system, new parts**	*Mechanical drawing package of cart-tipper sans hydraulic cylinder and supports* (225 points)
Fits and Tolerances: ISO system, new parts; both systems, standard parts **Fits and Tolerances: bearings; tolerancing methods**	*Modified mechanical drawing package of cart-tipper, with hydraulic cylinder and supports, numerous fits and GD&T specified.* (350 points)
Electrical drawings, esp. schematics and related symbols	Electrical schematic (reverse engineered from circuit board) (100 points)
GD&T: overview; geometric characteristic symbols; feature control frames **GD&T: modifiers, basic dimensions** **GD&T applications; tolerance accumulation**	*GD&T specified in mechanical drawing package of cart-tipper* (listed above).
Engineering standards and other sources of information	Treasure Hunt (technical information search project) (200 points)
Evaluation of commercial drawings	Commercial drawing evaluation (group oral presentations) (100 points)

Table 2: Industry Project Benefits

Benefits	Description
Seeing helps to believe; hands-on is the best approach	At first, the students perceived the amount of work and the level of difficulty as beyond their capacity. To lessen their fear, a few sketches of chosen parts were provided. Their job was to verify the sketches by comparing them with the hardware. As the students continued, they were able to improve the sketches, dimension them, add notes, and all the details necessary for a production drawing. As they learned more about the first simple parts, the students became progressively more productive and self-reliant. It was important that the hardware was readily accessible throughout the project. Students were able to verify the handouts, familiarize themselves with every part of the equipment, check the dimensions, and check the instructor for correctness. It was also the last resort when there was a disagreement about how a given part should appear on a drawing. It saved the instructor considerable time. Although all students had completed a first-semester materials course where they received repeated instruction on the use of calipers and micrometers, this project gave many students their first unstructured and only slightly supervised measurement opportunity.
Communication enhanced	Creating a pictorial address list of students encouraged communication and the exchange of ideas among students. All of the students agreed to participate and allowed their pictures to be taken, choosing individually which contact information to provide.
Both teamwork & learning enhanced	Each student created a complete set of drawings of the cart-tipper. They could freely exchange ideas among themselves. Several support groups were created at the very beginning of the project. When students became too frustrated, the instructor facilitated the cooperation by informing students about various ways of solving problems developed by individual students, or groups. A hint by the instructor that another solution method may exist was helpful without giving a ready solution. It was a pleasure for the instructor to see a satisfied student who solved a difficult problem on his or her own. As the project progressed, the students looked for different ways of solving their own problems, without help from the instructor or their peers.
Overcome problems	There was a sense of achievement at the end of the project when they were able to create all of the required drawings, after all of the frustrations and problems that did not seem to diminish. To some, the project appeared to be unduly fraught with frustrations and problems. The students that overcame their problems received the greatest level of satisfaction when the project was successfully completed.
Broad coverage	By sticking to one larger piece of equipment, broad topic coverage was possible. Overall, time was saved on explaining the function of a single comprehensive assembly versus multiple single-topic parts. The cart-tipper is a good example of a relatively simple device covering several important manufacturing techniques.
Keep organized	A project this size allowed emphasis on the importance of a good archiving system, both the naming and numbering conventions for the drawings, and file management on the computer. This project was close to what they will experience in industry.
Real-life experience aids students and industry	Working on current equipment exposes students to the recent technology in use by industry and keeps faculty up-to-date. Students learn that equipment may be built without proper documentation, and as a result, companies experience problems when the equipment needs to be manufactured in larger quantities. Some companies do not have designers to do the job. Having students develop project documentation affords the company a low-cost (essentially free) semi-to-highly skilled workforce, as well as strengthens the company's ties to the university. Knowing the company would utilize their product increased students' motivation.

Table 3: Drawbacks to Implementing an Industry Project

Drawbacks	Description
Too much expected	A company may have requests that cannot be fulfilled by student work, and which may interfere with the course objectives.
What to expect?	Often it is difficult to get clear requirements relative to drawings: The instructor is left to deduce company's preferences and practices with minimal support unless strong communication links are established.
Too much planning	One large project requires more detailed planning. The instructors may need extensive contact with the company, which may overload both instructors and company personnel.
Stuck with the project	Once the project has started, there is not much room left for modifications: The project has to be done, or the teaching institution's credibility may suffer. Similarly, the company cannot propose design changes after students begin the project without jeopardizing project completion.
Same again and again!	One large project may be "boring" for students. They are rarely exposed to fifteen-week class projects before their freshman year of college.
Overwhelming	Students may be overly frustrated at the start of the project when they realize how much work they have to accomplish. Although this can be reduced through careful planning, instructors need to work hard to combat the tendency to do nothing when a project appears to be too challenging.
Possessive	One project, however large, usually restricts the inclusion of other topics. Students cannot devote full-time effort to a single course. When they become engrossed in one project, other courses and assignments may be shortchanged.

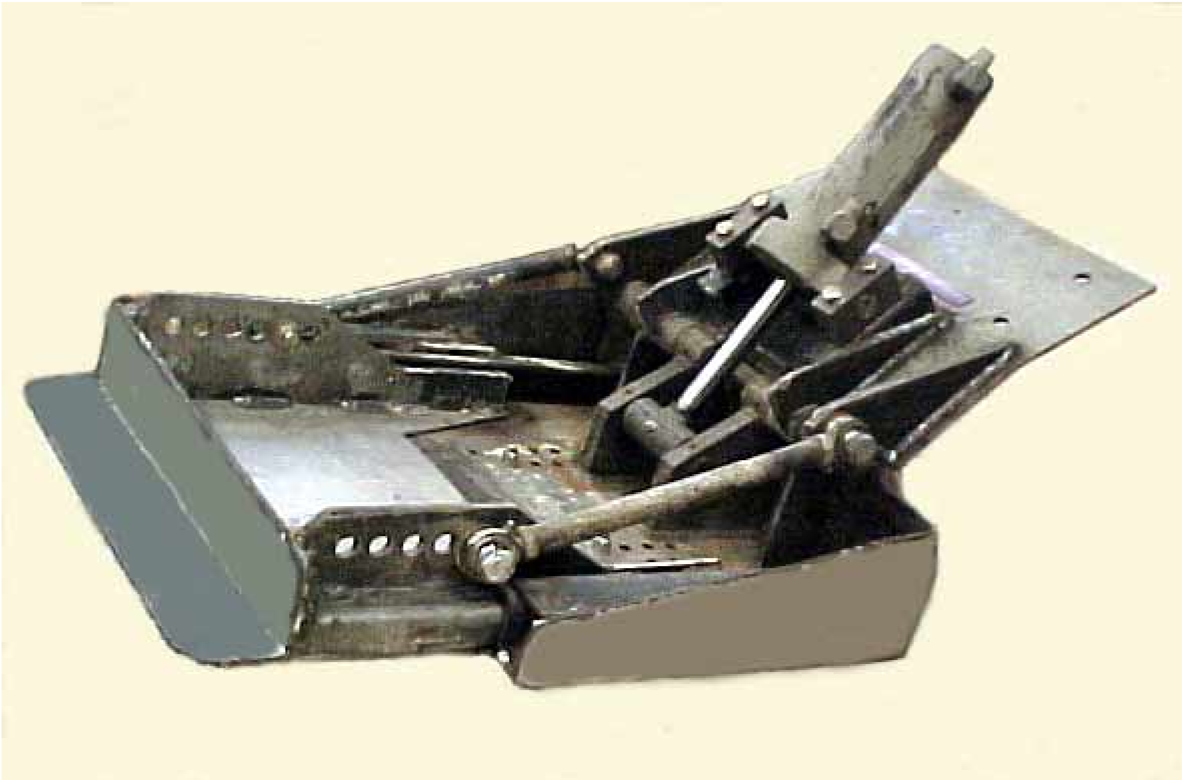

Figure 1: User-operated cart-tipper supplied by an Indiana company for a freshman reverse engineering documentation project.

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NANCY DENTON
Nancy L. Denton is an associate professor of mechanical engineering technology at Purdue University. She regularly teaches courses in design documentation, solid mechanics, controls, and machinery diagnostics. She has chaired the Women in Engineering and Mechanics Divisions of ASEE, and currently serves as the Editor in Chief of the *Journal of Engineering Technology*. She is a member of ASME and the Vibration Institute.

JAN LUGOWSKI
Jan T. Lugowski is an assistant professor of mechanical engineering technology at Purdue University. He gained industrial experience in the maintenance of mobile equipment, technology of aircraft engines, and design of fluid power systems.

JODY KNOLL
Jody Knoll recently joined Sun Microstamping as a quality engineer while seeking a Master of Science in Technology at Purdue University, specializing in industrial engineering technology. She completed her B. S MET degree at the West Lafayette campus in 1998 and has been involved with the design documentation course for three and half years. She belongs to SME and SWE, and has held several automotive industry internships.