Session 1566

Implementing a Cross-Course Design Project

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Abstract:

Juniors at Ohio Northern University are typically enrolled in three Mechanical Engineering courses during the fall quarter. These include ME 311, Process of Mechanical Design, ME 341, Manufacturing Processes, and ME 371, Numerical Methods. In the fall of 2002, the design project for the ME 311 course was altered to integrate material from these three courses. Student teams designed a part in ME 311, optimized its design (minimizing the material used) in ME 371, and built the part using what they learned in ME 341. In addition, finished parts were tested using a tension test, and students redesigned the part based on the results of that test. It is hoped that these changes will allow students to see connections between various courses, and force students to consider manufacturability, cost, and available materials when creating and evaluating a design. A student survey, as well as the functionality of the finished design, will be used to assess this new approach.

Introduction:

Based on the current curriculum, fall-quarter junior-level Mechanical Engineering students at Ohio Northern University are enrolled in three engineering courses. These are ME 311, Process of Mechanical Design, ME 341, Manufacturing Processes, and ME 371, Numerical Methods. Traditionally, the Numerical Methods course has been case-study focused, the manufacturing class has had a laboratory component in which students are given hands-on experience with basic manufacturing techniques, and the design course has included a project.

Ohio Northern University has implemented a continuous improvement process. While the full details of this process are not important here, it is noteworthy that, as part of this process, faculty meet quarterly to review faculty and student comments during Course Outcome Assessment. During our meeting after the fall quarter of 2001, The author discussed several of the problems noted after teaching ME 311 for the first time. The student interest level in the project was low, and, partly as a result of this, the project quality was low. Only a few of the submitted designs were capable of completing the required task, and students did not properly use the tools learned in other courses if those tools were not reviewed during ME 311. As such, it was recommended that, starting in the fall of 2002, the project in ME 311 would be modified to be a cross-course project, requiring students to apply what was being taught in all three courses in order to complete the project. In general, the students would use the design process learned in ME 311, optimize their design using techniques learned in ME 371, and build their design based on techniques learned in ME 341.

Using projects to help teach design and integration of courses are certainly not novel ideas. Faste, Roth, and Wilde discuss the importance of using projects in teaching design clearly, "We believe that any course without student projects is not a design course. That does not mean that such a course is bad or should not be offered, or that it is not of value to design education, we just mean it is not a design course. It certainly can be about design, but it is not a design course".[1] In addition, the importance of a 'culminating design project' has been stressed by ABET's new EC2000[2], and much work has been done describing such programs[3,4,5]. These capstone experiences tend to be focused on the student's senior year of studies.

Integration of course material across courses and projects has been recommended for some time[6]. Such integration is strongly encouraged at ONU, as can be seen in the College of Engineering strategic plan[7]:

> "The integration of engineering courses with mathematics, physics, and chemistry courses as well as integration within each department should be accomplished in order to provide the best learning environment possible for the students."

Much of the work done on integration of courses and on the integration of design projects across courses has been done at the first year level[8,9]. Some educators have combined the integration of the first year experience with seniors, having senior students work with first year teams[10]. Other educators have employed cross-disciplinary projects in order to expose students to a wider variety of problems, expose them to multi-disciplinary teams, and address ABET EC2000 requirements[11,12].

Work also exists on bringing design projects into the curriculum at the sophomore and junior levels[13], though this is less prevalent. In addition to doing projects, several educators have used hands-on experience and verification of analytic results to facilitate student learning[8,14].

At ONU, the modification to the fall quarter of the junior year was meant to enhance student learning by having them complete a project, with a hands-on component, which integrates material from several courses.

The change:

Obviously, creating a cross-course project requires cooperation among several faculty. Before classes began, in order to allow for the possibility of such a project, the Numerical Methods course was modified slightly in order to cover optimization at the proper time in the course. Faculty agreed that at least part of the case study that covered optimization would be directly related to the project design problem for the Process of Mechanical Design Course. The case study in Numerical Methods was the optimization of a very basic part design with the same design constraints, rather than each group doing their own design. This aided the faculty and students by allowing them to compare results to a 'correct' answer. Furthermore, the last week of the Manufacturing Processes course laboratory was left open so that students could use this time to build and prepare to test their part.

The project consisted of designing a part that would be capable of supporting a six kilo Newton (6kN) tensile load. The following diagram was provided to the students (Figure 1). Dimensions and loads were selected in such a way that final, full-scale parts could be tested on available equipment (an INSTRON 4467 tensile tester). The project description is intentionally vague, as a significant part of the course is spent on the process of problem definition.

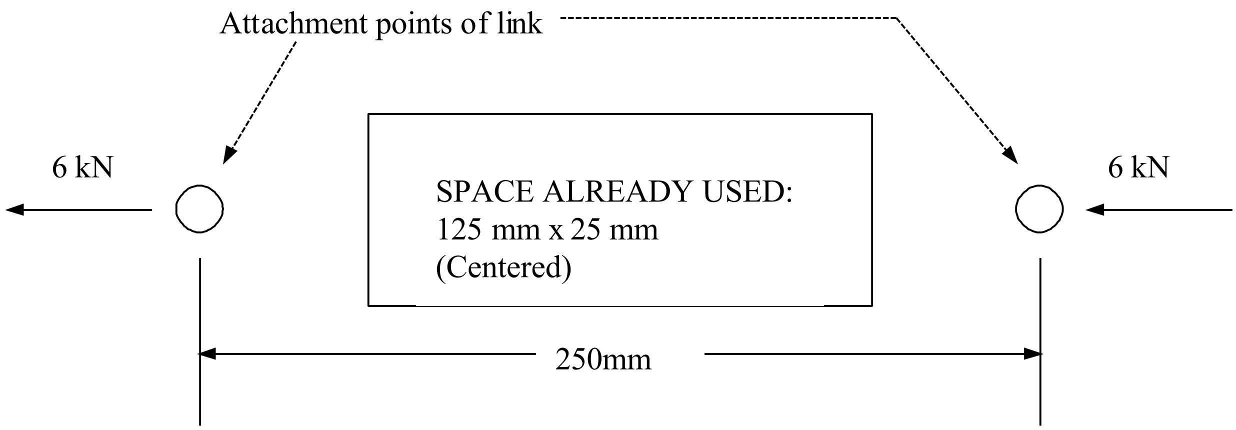

Figure 1: Project Geometry Description

Students were to work in teams of three. A total of twelve student teams were in the course. Each team was required to submit a final written report as well as their prototype part. In addition, assignments directly related to the project were due weekly, and were submitted as a team. Team members all receive the same grade for the project component of the course.

Results:

It was felt that there would be a significant benefit to all students to participate in this cross-course project, so no control group was used. Not all students in ME 311 were enrolled in both of the other courses due to scheduling conflicts. Students were required to choose their groups such that at least two members were in all three courses, so that each group, if not each student, would be exposed to the required manufacturing and optimization techniques. This allowed the projects to be completed successfully without requiring that all students be in all three classes, which would be extremely difficult for an upper-level course. It should also be noted that the standard course sequence already consisted of these three courses. No schedules were changed to accommodate this project – rather, the project was chosen based on the existing courses.

All twelve design teams submitted a prototype. On the Monday of the final week of classes, the class met in the laboratory and all twelve parts were tested (one such test is pictured in Figure 2). Of the twelve parts, only three did not successfully meet the basic criterion, of reaching a safety factor of two without failure (two parts had pins break, one deformed plastically). Parts that had not failed at this load were then subjected to a load three times the nominal load. Approximately three of these parts did not yield, indicating that these parts were over designed. Students were held responsible for designing their part such that it could be tested in the INSTRON machine, or to design and build any fixturing devices (beyond standard grips) required for testing.

Figure 2: Student part being tested

After these tests, student teams had one week remaining to submit their reports. Three teams chose to rebuild and retest their parts (two of them were teams whose parts had not met the basic criterion).

A very similar problem had been provided to the students the prior year (2001). Based on comparison of the designs between the two years, the final designs submitted as part of the cross-course project (2002) were noticeably improved. These improvements can be summarized in the following areas:

1. Performance: Based on analysis, less than one third of the designs submitted in 2001

would have met the basic load-bearing criterion. This was largely due to solid mechanics errors. It is felt that this was improved during the 2002 year for two reasons. First, having to do the optimization problem in numerical methods forced students to start the analysis sooner. The results of that analysis helped them to make some 'common sense' checks, and receiving a grade on their work gave them feedback about at least the basics of their analysis. Secondly, those students who did make significant errors realized those errors when they built and tested the part.

2. Manufacturability: Many design courses discuss the importance of manufacturability. Students clearly did a better job of considering this in the 2002 year, because they had to produce a prototype. Several student groups modified their design after they began to produce the part. One of the designs, (see Figure 3), consisted mostly of standard, easily purchased parts in order to make it as easy to produce as possible (it required only cutting the end plates to size and drilling 8 holes, along with assembly). Such considerations were not given proper weight by the 2001 class, since they did not have to produce the parts. Students were given access to ONU shop facilities to produce the parts, which gave them a limited set of options (equipment includes a welder, a mill, a lathe, a CNC, a drill press, and a press brake).

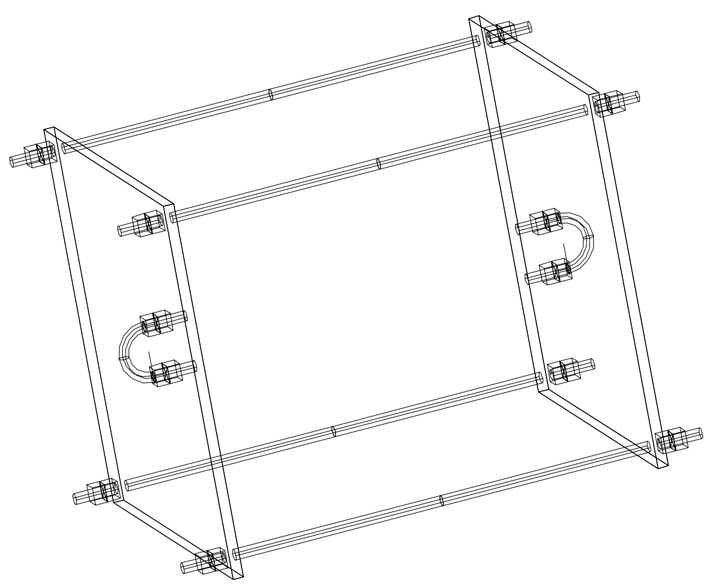

Figure 3: Wireframe of one student design

3. Cost Analysis: Because students had to choose and obtain specific materials, they were able to more accurately estimate costs.
4. Redesign: As mentioned earlier, three groups redesigned, rebuilt, and retested their prototypes. In addition, several other groups made design changes during the manufacturing process. In the 2001 class, no groups mentioned making significant design changes. In some sense, this should be expected – but it makes clear that students tend to think of a design as 'done' once it is complete on paper unless they have the opportunity to test it. In other words, they have no incentive to look at their 'final product' on paper and review it to see if improvements can be made. Building and testing the part provides

them with this opportunity.

5. Maintainability: Several teams wanted their part to 'survive' the tensile test. Therefore they designed the parts with shear pins, which could easily be replaced after the initial test. This is a good indication of taking maintenance into account in the design.

In addition to comparison with the prior year, students were given the following survey. The mean values are provided for each question:

Please evaluate these items based on the following scale:

5 – Strongly Agree
4 – Agree
3 – Unsure
2 – Disagree
1 – Strongly Disagree

____ 1. The course project assisted in my learning of teamwork tools. **(MEAN=4.6)**

____ 2. Working in teams helped me complete this project. **(MEAN=4.6)**

____ **3.** The course project assisted in my learning about selecting materials. **(MEAN=3.2)**

____ 4. The course project assisted in my learning about relating design to my engineering science courses. **(MEAN=4.1)**

____ **5.** The requirement to build the part assisted in my learning of the design process. **(MEAN=4.0)**

____ 6. The requirement to optimize and build the part helped me see the relationship between my design, numerical methods, and manufacturing courses. **(MEAN=4.0)**

____ **7.** The requirement to build the part was a waste of time. **(MEAN=1.9)**

____ 8. The requirement to have the part tested assisted in my learning of the design process. **(MEAN=3.9)**

____ 9. Having the opportunity to redesign the part assisted in my learning of the design process. **(MEAN=3.3)**

____ 10. Optimization and building of the part should be kept as a requirement of this course. **(MEAN=4.0)**

The students clearly felt that the project helped considerably in understanding teamwork, and that the teams helped in the completion of the project. Students were generally favorable about the project, feeling that it should remain part of the course, and that it assisted in their learning of the design process. Finally, they felt that this project did help their understanding of the relationships among their courses. The two disappointing results had to do with the selection of materials and the opportunity to redesign. Improvements will be made to the project next year in order to improve on these areas.

Conclusions and Improvements

It is felt that the introduction of a cross-course project which required students to design, optimize, build, and test a part has significantly improved the quality of project work in ME 311, Process of Mechanical Design. This improvement was clearly seen in the student cost analyses, the redesign and manufacturability of the part, and most importantly, in the performance of the designed part. Student surveys indicated that they enjoyed building and testing the part and that this helped them attain the learning outcomes of the course.

Further improvements are suggested for this project. The following is a short list of some the changes being considered for 2003:

1. Students may be required to design and conduct the testing of their part. They will be completely responsible for the collection and analysis of data, as well. To allow for more complete testing of parts, this testing will likely be done outside of the normal class meeting times.
2. Students may be required to construct the prototype for another group. It has been noticed by multiple faculty in several courses that students do not do an adequate job of documenting their designs (by drawings or other means). It is felt that having to produce a part purely from such documentation may help emphasize the importance of this step.
3. In conjunction with the requirement to construct another group's part, and to tighten the integration with the manufacturing course, a step-by-step manufacturing plan may be required.
4. The Mechanical Engineering Department, as part of curriculum reform discussions, is considering integrating the Process of Mechanical Design course with the Senior Capstone sequence (currently ME 411, 412, and 413).
5. Not all groups took advantage of the opportunity to redesign the part. This likely led to the low survey score on the question relating to redesign (question 9). Students may be required to redesign the part based on the experimental data.
6. A wider selection of materials will be provided, budgets permitting, in order to make material selection a more important and integral part of the design.

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Biography

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