Using Available Faculty Expertise to Add Relevance to a First Course in Heat Transfer

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Abstract:

Heat transfer courses for mechanical engineering students are typically lecture based, but often include an open ended project to provide a real world application for the theory being taught. Students often work in teams to produce a final report on their project. This helps to tie together the course and give relevance to the material being taught.

At Penn State Erie the open ended project has been taken one step further. A faculty member with expertise in some area of heat transfer is brought into the classroom early in each semester to make a presentation related to the semester long project with the intention of creating interest among the students in the project. The faculty expert remains available on an ongoing basis to serve as a consultant for the students, and comes back to the class one or two more times to present more advanced information about the project. The students complete the project requirements at their level of expertise, but the experts go another step to demonstrate other analysis methods using commercially available software commonly in use in industry.

This method has been used for two years with good success. The first year the students were required to design a cooling system for an injection mold for a plastic part, and the second year the project was to design a heat sink to cool a Pentium 4 processor. In the second year the project went another step adding a non-graded competition to determine the best heat sink design. These projects provide a theme to build the class on each year, help to maintain the students' interest level in the course and demonstrate the relevance of the material to actual applications.

This paper describes the role of the faculty experts in facilitating the semester project, and how it has already changed in the first two years. The two projects which have been used are outlined, and a summary of results is included.

Introduction:

Semester projects for heat transfer courses are common for mechanical engineering students. The projects provide a means to tie together the material being taught during the semester, and help to give the students a feel for the relevance of the subject. These projects are typically worth about 10-15% of the overall grade, so students should spend about that percentage of their time for the course working on them. Working in teams helps to reduce the time burden on individual students. The students are usually third year students, and the heat transfer course is a three credit course.

At Penn State Erie a new dimension has been added to this project. A faculty member other than the instructor, who has special expertise in the area of the project, referred to herein as the "expert", is made available to provide insight and guidance throughout the semester. Many faculty members, particularly the engineering technology faculty, have a significant amount of industrial experience, so a wide variety of potential project experts are available. This has been tried for two years with good success, and plans are for it to continue. The expert can provide the students with valuable background information to help them realize the importance and relevance of the project to real world situations. The students seem to appreciate this. Since the expert is another faculty member, he/she can be available on a regular basis as a consultant during the entire semester.

The first year that this concept was used the students were required to design a cooling system for an injection mold for a plastic part. The expert was Martin Dropik, a Lecturer in Engineering and former design engineering manager at Fisher Price with an expertise in injection molding and mold design. The primary role of this faculty member during the first year was to present a lecture on plastics design and processing, and provide relevant data. The experience led to a more involved role during the second year. Details of the first year experience and suggestions for other possible projects in the plastics field are given below.

The second year of this concept the project was to design a heat sink to cool a Pentium 4 processor. The faculty expert was Robert Edwards, a Lecturer in Engineering with a research interest in thermal management of electronic equipment. The students worked in teams of three to four. Design details for the Pentium 4 chip were given to the students, and several design constraints were made. Details of the project are given below.

As stated, the role of the faculty member was increased during the second year. During the first year the faculty member primarily provided background information so the students could see the relevance of the project to a real life situation. In the second year, in addition to providing background information and data about the project and to answer any questions the students might have, he also made himself available during the semester to function as a consultant on the project. He also analyzed each of the designs using Flotherm software to demonstrate to the students one use for this commercially available software and to provide a basis for comparison with actual test results. Finally, he actively participated in the non-graded contest at the end of the semester.

The Projects:

The first year project was to design a cooling system for an injection molded plastic part. It consisted of designing the size and location of the cooling passages in a water cooled mold to uniformly remove heat from the plastic part. The students had to design a water channel cooling configuration, determine a water flow rate, and analyze the cooling plate using a steady state

ANSYS model. Since the analysis focused on the mold cooling and not the plastic part cooling, a steady state analysis was sufficient.

Figure 1

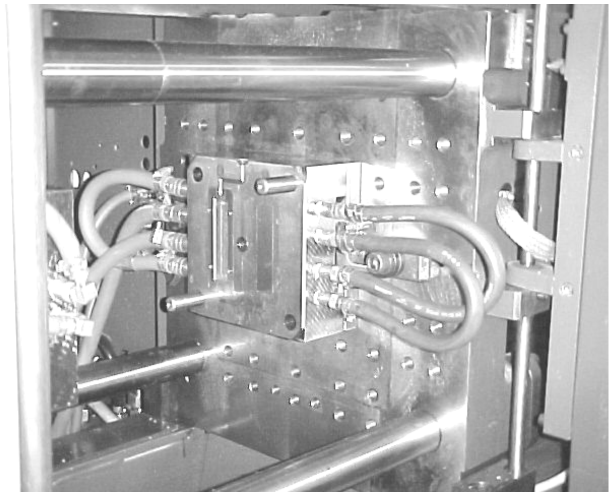

Figure 2

The students also learned that there are factors other than technical considerations which must be taken into account in the design process. The expert took the students on a tour of the plastics processing lab shown in Figure 1. They were able to see how some of the processes described in the classroom are actually done. The cooling processes were stressed, and students had an opportunity to see first hand the equipment used for cooling, and some of the designs used for cooling various molds.

The students worked in teams of three to four for the project. They were required to find an economical solution for cooling an injection mold used for molding a simple flat plate of plastic. Figure 2 shows cooling lines entering a small injection mold, similar to the one the students were working with. They were given various thermal properties of the plastic being processed, including density, specific height, and total part volume. They were also given the process temperature and the required final part temperature.

The students were required to do several things for the project. They first had to determine the total amount of heat that had to be removed from the plastic part. Once this was determined, they had to research conventional plastics industries practices for heat removal, including typical water flow rates, water temperature and temperature rise, and cooling time. All of these parameters were to be factored into a manual calculation for their particular design. After a design was agreed on by the team, an ANSYS model was built, and a steady state analysis was completed. The students were required to write an engineering report on their design to conclude the project.

The second year project was to design a heat sink to cool a Pentium 4 processor. The faculty expert attended an early session of the heat transfer class to discuss the importance of thermal management of electronic systems, how it was related to the heat transfer course, and to show the students some of the hardware currently being used for cooling electronic components. The purpose of this meeting was to provide background information and to build interest among the students for the semester project. In addition to the initial meeting, the expert attended several key classes during the semester to answer questions about the project, and actively participated in the non-graded contest at the end.

Students were given several design constraints. The constraints were in conflict with each other, so student teams had to make decisions about optimizing the design. The heat sink had to fit within a particular physical space and must be designed to attach using standard mounting holes on a Pentium 4 motherboard. Parallel fins were to be used as a base design, but the students were encouraged to explore other designs as an alternative to their base design. Room temperature air was to be blown across the heat sink in a direction parallel to the fins. The baseline design was to be made from aluminum, but steel was also to be analyzed for comparison. The manufacturing costs and material costs were to be minimized while the cooling capacity was to be maximized. The material costs were determined based on the overall weight of the part, and the students were given a formula by the school technician for determining the manufacturing cost based on the number of fins, fin spacing, fin depth, and fin thickness.

The students used manual fin equations to determine a preliminary design for their heat sink. The calculation assumed that the heat sink was isothermal. After the team agreed to a design, a 2-D steady state ANSYS analysis was done to confirm the preliminary manual calculations. Students were required to present a final report on their design. The report included all of the preliminary and final calculations for both the baseline design and any advanced designs they tried, a comparison of strengths and weaknesses of the two designs, and any conclusions and recommendations they had. Figure 3 shows some of the heat sink designs from the student teams.

It was decided to provide extra feedback to the students by adding a non-graded contest at the end of the semester, and the expert was to provide separate calculations to verify the student designs. Each heat sink was manufactured and mounted on a Pentium 4 thermal simulator (see Figure 4), and 50 watts was applied. The maximum surface temperature of the simulated chip was measured. Prior to the testing, the faculty expert analyzed each of the heat sinks using Flotherm software to see how well the test results would match with the predictions. Figure 5 shows a typical Flotherm output. This extra feedback to the students seemed to help keep the interest high among the students for the project.

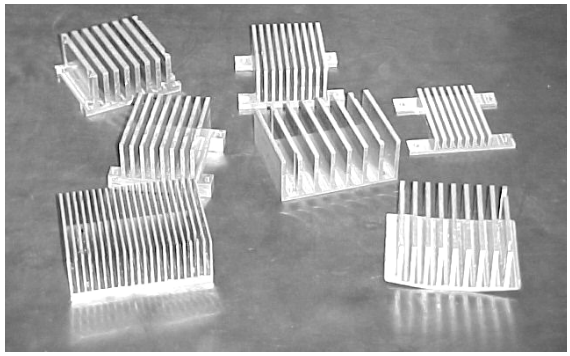

Figure 3

Figure 4

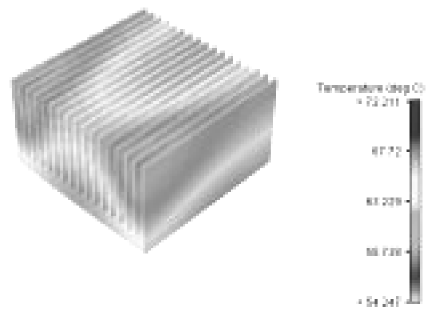

Figure 5

Feedback From the Faculty Members:

The faculty members that served as the "experts" are in agreement that they would do the projects again.

After the first year experience where the input was primarily provided early in the course, several suggestions arose for future consideration. The question is whether the students had gained some understanding of the importance of the various parameters or if they were simply going through the process of completing a project. This is important since the purpose of bringing in the expert is to provide the students with a deeper understanding of the project, and to demonstrate relevance of the material being taught in the classroom to real world designs. This suggested an enhancement to provide feedback to the students on their designs by either designing an experiment to verify one or more of their designs, or by using software such as Moldflow to give a comparison with their manual and ANSYS calculations. This is beyond the scope of the students involvement, but could be done by the expert.

Thus, the role of the faculty expert was increased for the second project. He was available throughout the semester to answer questions, and to provide further insight into the project, and participated in the end of semester project. Extra feedback was provided to the students through

Flotherm analysis which they can compare to their manual and ANSYS calculations. Since the expert is on campus, students are encouraged to take more advantage of his/her availability during the semester. The expert suggested that the formal reports from the student teams should demonstrate their increased depth of understanding of the project brought about by their interaction with the expert.

The third project currently under way is similar to the one for the second year. The students will once again work on the design of a heat sink for a Pentium 4 processor. The final contest has been dropped for several reasons. First, the class is larger, and the cost of manufacturing the heat sinks is prohibitive. Also, the testing time would be a problem. Equally important, reasonable machining limits put significant constraints on design space. The feedback to the students this time will be by way of a Flotherm analysis of each of the designs which gives the students much more flexibility to be creative with their designs. The Flotherm feedback will not be a factor in the grading, but is intended to provide some further insight into the problem of heat sink design. Students will be graded on manual conduction and convection calculations, ANSYS analysis, and a formal report. The report must include evidence of a depth of understanding of the problem beyond what would be learned during the regular lectures. The faculty expert will be available throughout the semester to provide insight and to answer any questions that may arise. Students will be surveyed at the end to determine their thoughts about the project, and particularly about the role of the expert.

Student Feedback:

Students were informally surveyed after the second project. The feedback was generally positive. We will conduct a more formal survey after future projects, including the current project.

Below are some of the comments received from the students:

- "I think the heat sink project was definitely worthwhile. The design really taught me how to think about the theory I was learning and to understand assumptions that are necessary to solve any real life scenario."
- "To address the idea of bringing in someone with more knowledge of the subject, I think that it's a very good idea. The more we can learn about the subject, the better, right? And who better to learn from than a man who already has extensive knowledge in that subject."
- "I think the heat transfer project was a valuable part of the course. It is important to apply the fundamental equations that we learned in class to actually design something rather than just doing simple homework problems."

Conclusions:

Semester projects for undergraduate mechanical engineering students are very common. It is not uncommon for students to work on these projects in somewhat of a vacuum in terms of any relevance to real world situations. Bringing in faculty experts to serve as semester long consultants can greatly enhance the learning experience for the students by providing examples of real life uses for the work, insight into the problem, and valuable feedback to the students. Having the faculty expert on campus provides the students with timely assistance on the project. This aspect of the project will be emphasized more for future projects. Fortunately, at Penn State Erie, The Behrend College fully two-thirds of the faculty have significant industrial experience providing an in-house wealth of available expertise. At Penn State Behrend the use of faculty experts in the heat transfer course will continue to evolve to find the right amount of involvement by the faculty experts

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