AC 2007-1674: IMPROVING INTERDISCIPLINARY CAPSTONE DESIGN PROJECTS WITH COOPERATIVE LEARNING IN THE MEDI-FRIDGE PROJECT

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Abstract

As research at many institutions becomes more and more interdisciplinary, there is a desire to incorporate such themes into the undergraduate curriculum, specifically by offering interdisciplinary capstone design experiences to senior-level students. At Rice University, faculty responsible for capstone design have found it increasingly challenging to make such experiences beneficial to students, since much knowledge needs to be gained at the intersections of the disciplines. This must usually occur throughout the design process and is specific to a given project. The result has historically been "division of labor", where students more comfortable with given aspects of a project take ownership of those portions, while the other students are typically unwilling to acquire the "new" knowledge related to the project. In an attempt to reverse this trend and have more beneficial interdisciplinary design experiences for our students, our mechanical engineering and materials science program has adopted principles of cooperative learning to improve team performance, increase knowledge acquired, and promote truly interactive experiences in the capstone design course. This paper will highlight the revisions to the course and will use one project (the Medi-Fridge) as a case study for the effectiveness of these implementations.

As an example project for these course revisions, this year a group of senior engineering students (three mechanical engineering and two electrical engineering students) worked on a method to keep medication cool for extended periods of time. This capstone team has developed designs which will provide a solution applicable in many instances and locals.
More and more medicines are being developed that allow patients with serious diseases such as multiple sclerosis, diabetes, aids, etc. to live longer and in many cases fuller lives. A common thread among these medicines is that most of them must be kept cool until they are used. The refrigeration requirement can be a serious problem in third world countries and serious inconvenience in the United States or other developed country for people that need/want to travel for some period of time. This project has all the capstone design requirements, but also has the strong motivation of helping people that suffer from life threatening and debilitating diseases.

Introduction

Seniors at our institution are required to take a capstone design course when pursuing a Bachelor of Science degree in mechanical engineering. In recent years, the course instructors have attempted to offer increasingly interdisciplinary projects, and have recruited students from other departments (bioengineering, electrical and computer engineering) to form interdisciplinary teams to tackle these topics. The capstone course is designed to allow the students to use their undergraduate course work in a practical application project. There are various topics available to the students and range from competitive industry sponsored projects to medical related projects.

As the number of interdisciplinary projects has increased over the years, we have seen a trend of increasing interest in such projects, increasing need for new knowledge throughout the project period in order to successfully complete the project, and an increasing divisiveness among teams, especially those involving students from multiple departments.

In response to these observations, cooperative learning methods have been incorporated into the course. Cooperative learning has been shown to improve student-faculty and student-student interaction, information retention, higher-level thinking skills, motivation to learn new material, teamwork, interpersonal skills, and communication skills, all of which encompass the goals of our capstone design course[3].

There are a number of criteria that must be met in order to ensure that cooperative learning is taking place. These are: positive interdependence, individual accountability, face-to-face interaction, interpersonal skills, and group self-assessment[2].

This paper will discuss specific activities adopted for the course to ensure that cooperative learning is taking place. We will then present a case study for a single student project and discuss the direct benefits of the new course structure. Finally, we will present conclusions related to the course revisions, and a plan for future assessment of the changes.

Methods

To ensure that we are truly implementing cooperative learning techniques, we have adopted a set of activities and policies for the capstone design course. This section will outline the five areas required for cooperative learning and our specific activities, based on suggestions of Felder, Brent, and Stice[5]. Also presented, will be some discussion of our methods for team formation.

Positive Interdependence

To promote positive interdependence, we must create an atmosphere where team members must rely on one another to achieve their goal. When any team member fails, this must reflect on the group as a whole[2]. For this facet of cooperative learning, we have implemented two revisions. First, we have adopted jigsaw activities[4]. In the jigsaw workshops, at least one representative from each group must attend one of three workshop topics that provide support information and resources for the teams. These expert groups have addressed topics listed below. Then, the experts return to their groups, share the information, and all team members are responsible for the knowledge. These activities serve a number of purposes. We have been able to cover more lecture material than in years past, since we can effectively give three times the course content in one lecture period. Additionally, the interdependence is built in to the activity, satisfying the cooperative learning requirement. Another policy that we have instituted is a financial bonus to teams with strong Project Pitch presentations. These presentations take place approximately one third of the way through the first semester of the capstone course, and require students to answer why the problem they are addressing is important, why existing solutions (if any) are inadequate, why their proposed solution is the best one, and how they will do it. The audience for the presentation is potential investors, who must decide which groups are the most convincing and have the best plan. Student and faculty evaluations of the presentations are tabulated, and top performing teams (for example, the best three out of ten) get additional discretionary funds for their team which may be used to purchase team shirts, sponsor a team outing, or purchase additional materials for the project prototype.

Sample Jigsaw Workshop Topics:

- Log books and project books
- Effective reports and presentations
- Project planning
- Procurement and shop policies
- Rapid prototyping equipment use and procedures
- Resources and budgeting
- Ethics
- Patents
- Experiment design and uncertainty

Individual Accountability

In order to meet the individual accountability requirement for cooperative learning, all students must do their share of the work and must master the material to be learned. We have adopted an exam on project content to make sure that all group members are aware of the major design decisions related to their project. Also, we ask students to self-report their time spent per week on the project, and use this, along with their participation in weekly meetings with the faculty advisor, to gage their mastery of the material. Individual performance (based on the exam, participation, log book, and level of involvement) accounts for 50% of the student's grade in the course.

Exam on Project Content

1. Consider the actuation supplied to your prototype system, or consider the power source if your prototype will run on batteries.
    a. Describe your team's final selection for the actuation or battery power for your device.
    b. Describe at least one alternative choice that was considered.
    c. List 3 reasons, either in favor of your choice, or against your discarded option, that led to your final design decision with regard to actuation or battery power.

2. Consider sensing in your prototype system (any sensor package or test mechanism that you will use to measure important quantities related to your prototype).
    a. Describe your team's final selection for sensing for some aspect of your device.
    b. Describe at least one alternative choice that was considered.
    c. List 3 reasons, either in favor of your choice, or against your discarded option, that led to your final design decision with regard to sensing.

3. Describe (qualitatively) two performance requirements for your prototype device. Then, put these performance requirements in terms of quantitative values, and explain (in words, or with equations if you like) how you arrived at these quantitative performance specifications.

Face-to-face Interaction
Face-to-face interaction is a critical component of cooperative learning. All groups have weekly meetings with their faculty advisors, and meetings without the advisor, to touch base, address issues, and resolve open decisions. We have also implemented a new peer feedback activity for presentations and the initial design plan written report. These activities are based on the Calibrated Peer Review method[1] but do not use the online software.

For the presentation peer review, the instructor distributed an evaluation rubric and then played a video tape of a previous year's group to the class. Students were asked to individually fill out the rubric, and then the instructor led discussion to determine what constituted different point scores on the evaluation rubric. The following week, each group brought hard copies of their presentation slides. Teams were paired up and exchanged slides. Individually, the team members evaluated the content and design of the slides, and the organization of the presentation, according to the rubric used the previous week. Then, the group discussed their individual evaluations of their peer group. Finally, the peer groups exchanged feedback on the presentation slides. This resulted in much stronger Project Pitch presentations this academic year compared to prior years, since students had seen a number of examples, and had worked through the rubric to understand the evaluation methods that would be employed.

For the first written report, the Design Plan, the CPR method was also used. The design plan is to include a statement of the project's goal, a statement of the design problems, a summary of research completed and that still required, a detailed schedule for completing the design by the end of the semester and assignment of individual tasks for accomplishing the design, and a rough budget estimating overall costs for the project. Again, one lecture period was used to calibrate the review process, using sample student material from prior years. Common "offenses" were highlighted and discussed after the students read and evaluated, individually, the sample work. Then, in a follow-up lecture, students brought their draft design plan documents to class and exchanged with their partner peer group. The feedback methods used for the presentation CPR activity were repeated. Again, improvements in the design plan document quality were noted this year, with a decrease in the number of typical "offenses" committed by students. This was accomplished primarily through peer rather than instructor feedback, and through the face-to-face interactions of the students.

It should be noted that the Jigsaw activities also contribute to face-to-face interactions in the course.

Collaborative Skills
The jigsaw and financial bonus activities are inherently collaborative activities that fulfill the collaborative skills requirement for cooperative learning. However, we have also added a lecture on forming requests, responding to requests, and forming complaints to give the students experience with these activities. Finally, groups are formed early in the fall semester and stay intact for the full year in order to emphasize the need for true collaboration among members.

Group self-assessment
All groups are required to develop plans for their projects, with milestones and resource and personnel assignments for each task. These schedules are revisited throughout the year. Also, at

the break between semesters, a lecture on teaming, focusing on conflict resolution is conducted so that teams are armed with the proper tools to deal with any dysfunction.

Forming teams
Teams are formed by the course instructor, with a group size of 3-5. All project topics are presented to students, along with a supplemental handout and contact information for each project sponsor. Students are then asked to complete a project request worksheet that includes information about their GPA, specialization area, preferred project topics, preferred team members, and their schedule. The course instructor then forms groups, balancing the preferred project, team members, student ability, focus area, schedule, gender, and ethnicity of each student. For an institution the size of Rice, with approximately 35-40 students in the course each year, this method has proven feasible.

Medi-Fridge Project Background
More and more medicines are being developed that allow patients with serious diseases such as multiple sclerosis, diabetes, aids, etc. to live longer and in many cases fuller lives. A common thread among these medicines is that most of them must be kept cool until they are used. The refrigeration requirement can be a serious problem in third world countries and serious inconvenience in the United States or other developed country for people that need/want to travel for some period of time.

This year at the suggestion of a faculty member, a group of senior engineering students worked on a method to keep medication cool for extended periods of time. Using brainstorming techniques, this capstone team developed designs which provide a solution applicable in many instances and locals.

The existing concepts use a form of ice to maintain an acceptable temperature for 18 -24 hours but need refrigeration to refresh the ice pack after this time period. The target for this project is to maintain a month's worth of medicine between 36° and 46° F for an extended period of time. This target requires an excellent insulation and regenerative method to provide cooling in a simple accessible manner. This project has all the capstone design requirements, but also has the strong motivation of helping people that suffer from life threatening and debilitating diseases.

Medi-Fridge Design
Originally the overall approach had been a vacuum insulated unit with thermoelectric coolers (TEC's) powered by a battery pack to maintain internal region for the medication at the desired temperature and recharging the battery pack overnight. Using the brainstorming techniques learned in earlier sessions of the course, the group reviewed the possible power issues. The project goals evolved into a unit that would provide proper medication storage for at least 24 hours (preferably 48 hours) and could be "rejuvenated" with a 6-10 hour access to conventional AC power.

This concept evolved to a vacuum insulated unit with a quantity of re-freezable ice to maintain the desired temperature for a reasonable time (during the day) and a method of refreezing the ice in a short period of time (a portion of the over night period). Nominally the target was to have a unit that could maintain the desired temperature during the day and be recharged over night.

The group reached a consensus that this set of specifications did not solve the desired capabilities for the African aids need, but would be achievable and meet a serious need in many developed countries for medications needed during extended travel.

Final Design

The design is currently being constructed and will be tested in the coming months. The current design consists of a vacuum insulated container with central storage area, surrounded by a layer of gel ice. A thin metal sleeve fits between the gel ice and insulating cylendar wall. Atop the metal sleeve is a metal plate with thermoelectric cooler (TEC) attached. On top of the thermoelectric cooler is a finned fan assembly. This whole upper assembly is covered by a cap which attaches to the vacuum insulated cylinder. This assembly can be seen in figure 3. The operation of the device is as follows:

- **Active cooling mode**: overnight or for a 6-10 hour period, the cap is off the container for active cooling (see figure 3). The TEC is plugged into an A C outlet through an external transformer adapter. The A C power is converted to D C and the voltage is reduced with this external adapter to meet the TEC and fan requirements.
- **Passive Cooling Mode**: after the gel ice is frozen, the power is disconnected from the TEC and the cap is placed over the assembly and attached to the vacuum insulated cylinder (see figure 4). In this mode, the unit can be carried or placed in luggage. The gel ice will maintain the desired temperature for up to 48 hours.
- Figure 1 shows the TEC cooling assembly with metal base and sleeve.
- Figure 2 shows how the TEC cooling assembly fits into the insulated cylinder.

Medi-Fridge as Case Study

This project was carried out under the course innovations described above. Positive interdependence was helpful in this team's results. The jigsaw technique was used on many of the class sessions for instruction of basic course/project considerations (items noted above).In regard to the bonus incentive, this team was one of the three teams to win a bonus for their budget in the project pitch competition. The jigsaw activities helped strengthen the teamwork of the group and the topic was a strong motivator for the project pitch and their interest in the project topic. As in earlier projects, brainstorming techniques were used successfully to reach an improved solution to the original approach.

In previous years, students in several similar interdisciplinary projects lacked team cohesiveness in the execution of the project. Some students would work almost alone on their specialization and not interact with the team meeting only minimum instructor requirements for group meetings, etc. Collaborative learning course revisions provided improvement in team involvement in the current year's project.

In some of the previous projects, responsibilities for specific parts of the project work were not always clear and as can often happen "everyone's responsibility is no one's responsibility". Without clear lines of responsibility things can fall through the "cracks". The jigsaw activities were very effective in avoiding this by forcing a line of responsibility for the various components in the course.

Additionally in previous year's projects, often students have done their share of the effort, on a specialized part, but have not had a proper grasp of the overall project. This was a problem in several of the previous interdisciplinary project groups. It was clear that several of the mechanical engineering students did not understand the electrical aspects of their interdisciplinary project. The exam on project content showed this team's knowledge was very good in regard to understanding the overall project and it was particularly heartening that the mechanical engineering students showed a solid understanding of the electrical aspects and needs of the project e.g. the type of electrical circuits required. Having an exam on project content planned at semester's end was useful in forcing the students to be aware that they were expected to have a general understanding for the entire interdisciplinary project.

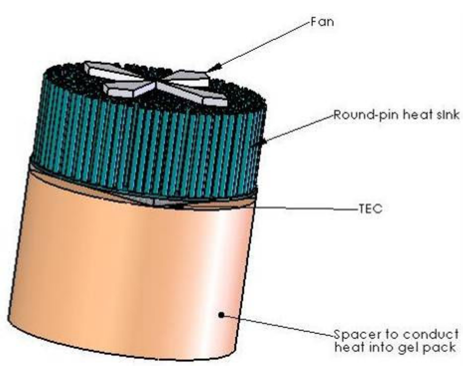

Figure 1: TEC Cooling Unit

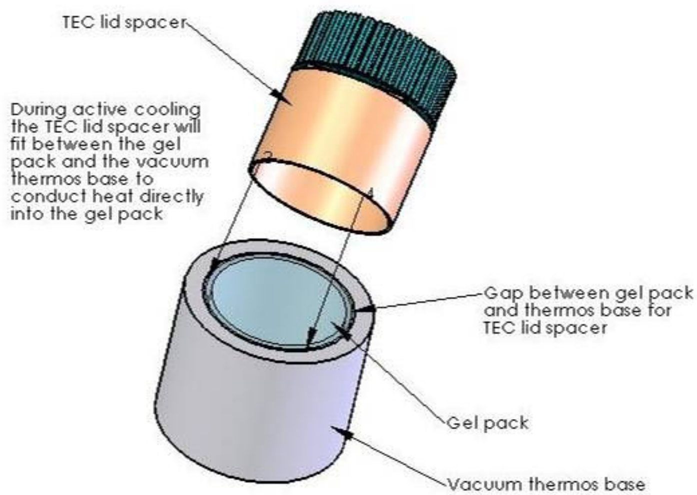

Figure 2: TEC Unit and Insulated Cylinder

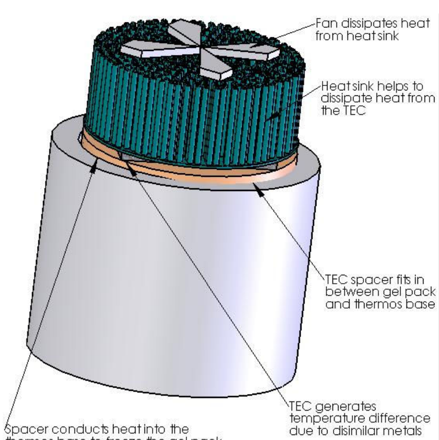

Figure 3: Active Cooling Mode

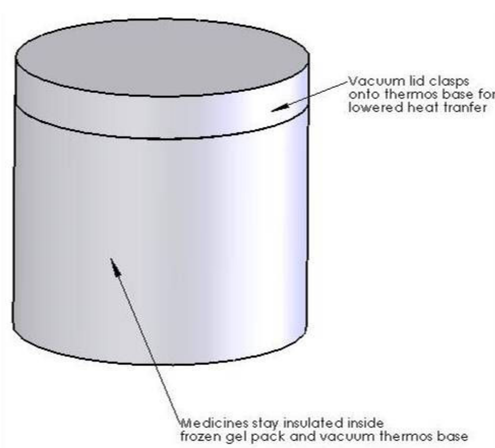

Figure 4: Travel Mode

Conclusions

- Compared to similar projects done the previous year the recent collaborative learning course revisions provided improvement in team involvement, overall project knowledge, and group interaction.
- The jigsaw activities provided more coverage of project work basics and had a positive influence on group interaction and team involvement
- The exam on project content showed the mechanical engineering students had a solid grasp of the electrical requirements and control concepts
- This project provided an excellent design development experience for the mechanical engineering and electrical student. It has followed the classic design procedure of defining the problem, brainstorming, determining specifications, locating components, making other components, assembly, and testing.
- The Medi-Fridge project is an excellent engineering project in that it has the typical engineering tradeoffs required to reach a satisfactory approach that meets the project goals.

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