FRESHMAN-SENIOR COLLABORATION IN A CAPSTONE DESIGN COURSE

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ABSTRACT

An innovative capstone design course titled "Design of Fluid Thermal Systems," involves groups of seniors working on various semester-long design projects. Groups are composed of 3, 4 or 5 members that bid competitively on various projects. Once projects are awarded, freshmen enrolled in the "Introduction to Mechanical Engineering" courses are assigned to work with the senior design teams. The senior teams function like small consulting companies that employ co-operative education students; e.g., the freshmen.

One of the objectives of building this collaboration is a desire to increase the retention rate of the freshmen by involving them with the seniors in what appears to be some interesting design work. Additionally, the seniors benefit by developing the ability to communicate their ideas to a non-technical audience as their design work progresses.

At the conclusion of the semester, an assessment was made of this program to determine its effects as perceived by the senior students with the following findings:

- Overall, the seniors perceived the freshman-senior interaction as a rewarding experience
- The seniors perceived their freshmen partners as able to make useful contributions.
- The seniors gained an appreciation of management theory through coordinating their freshmen partners.
- The seniors did not perceive they were able to positively influence the freshmen regarding retention in engineering.
- The seniors recommended that the program be continued in the future.

Results of several specific design projects are highlighted, and the freshman-senior interaction is described.

BACKGROUND

"Design of Fluid Thermal Systems" is a senior-level, capstone design course at the University of Memphis. Students in this course are divided into groups of 3, 4 or 5 members who work together as a team on a design project. Selected projects are presented to the design teams who must bid competitively on three of the projects. The design team with the lowest bid is awarded that particular project to work on for the entire semester. (See the text listed in the Bibliograpy for information on the bidding process.) Design teams are treated like companies and as such, each group chooses a company name and designs a company logo. Titles of projects worked on in Fall 2001 are provided in Table 1. Some groups developed web sites for their companies. More detailed project descriptions are provided in the Appendix of this paper.

Table 1. *Project titles and company logos.*

Title	# of Engrs	Student Designed Logos
A "Bad Guy's" Pond	3	
Determination of Valve Coefficient	4	
Flash Freezing of Chicken	5	
Pneumatic Freight Pipeline	3	
Fireplace Heat Recovery	4	

Groups elect a Project Director who meets with the course instructor on a weekly basis. The Project Director works with the group members to identify a list of tasks to complete in order to finish the project by the end of the semester. The list of tasks includes, for example, sizing and selecting a pipe to convey a specific fluid; sizing and selecting a pump; selecting a heat exchanger; predicting system performance; and writing a report about the design of the system.

When the tasks are identified, a completion date is selected for each one. By the end of the fifth week of the semester, for instance, a pipe material and size will be selected. The tasks and target completion dates are summarized in the form of a task planning sheet. Also included on the task planner is the name/initials of the individual responsible for completing the task.

Each group member keeps and maintains a notebook or diary of all tasks completed for the project. The diary contains any and all details of the work done by that particular member on the project. This would include something as short as a phone call, or as detailed as calculations to predict when a pump will cavitate.

Table 2. *List of tasks to be completed for the Fireplace Heat Recovery Project.*

	Week Number									
Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Research existing fireplaces	■	■								
Select fireplace		■								
Suggest Heat Exchanger designs		■	■							
Decide on HX design & optimize			■	■						
Optimize blower				■						
Do cost analysis				■	■					
Develop CAD models & plastic parts		■	■	■	■					
Write Report						■	■	■		
Write oral presentation						■	■	■		
Finalize Report									■	
Finalize oral presentation									■	
Present & submit reports									■	■

The Project Director meets with the course instructor on a weekly basis, and brings his/her group member's notebooks. The instructor checks to be sure that the group or company is working on schedule. If so, the "company" earns a satisfactory performance evaluation for the week. If not, the company's performance is deemed unsatisfactory and repeated unsatisfactory evaluations will affect the group's final grade. A student who continually fails to perform satisfactorily is "fired" from the company by the instructor.

COOPERATIVE EDUCATION

Once projects are awarded, student companies begin their work. The first thing to work on is the task planning sheet. Tasks must be identified and the individual responsible for finishing each task is assigned.

A new series of two courses has been introduced into the Mechanical Engineering curriculum at the University of Memphis. Among other things, these courses serve as an introduction to Mechanical Engineering and will hopefully aid our retention efforts. One of the ideas tried in Fall 2001 was to get the freshmen involved with the seniors. Seniors can provide valuable insights to the freshmen and provide them with a perspective about the University that faculty cannot provide. The seemingly ideal way to do this was to have the senior design teams take on freshmen as part of their companies. Thus, the design "companies" were assigned to take on "co-op" students.

Certainly freshmen are not expected to be able to size pumps or to make engineering-based decisions on materials to use for food handling. There were, however, things that the freshmen could do to work credibly with the seniors.

For example, one company in Fall 2001 was assigned the project of designing a pneumatic freight pipeline. The pipeline would use a high volume flow rate of air to convey raw or frozen peas from a feed hopper to a cyclone separator. The students were to select a pipe size, a suitable blower, a feed hopper, and a separator. In addition, the students were to consider economic, environmental, health, and safety issues, as well as determine the cost (initial plus operating) of the entire system. The properties of peas were needed in order to size the pipeline. The freshmen were assigned the task of measuring the properties of peas, and with some statistical significance. (With a 95% confidence level: the density of peas is 1 410 kg/m^3, and the diameter of the "average" green pea is 0.23 in.)

In another project, one company was assigned the project of designing a system to flash freeze chicken stored in 40 lb boxes. The students were to have the chicken frozen within 24 hours and could do so with a conveying system designed for continuous or for batch operation. The students were to consider economic, environmental, health and safety issues according to FDA guidelines, and to determine the cost (initial plus operating) of the entire system. The properties of chicken were needed in order to determine cooling times. Freshmen made thermocouples, inserted them into raw chicken pieces and froze the chicken. Data on temperature versus time for freezing of chicken were obtained and used for system design.

Typically, there were 3 freshmen assigned to each senior; that is, each company had at least 10 freshmen co-op students to work with. The seniors (technically experienced persons) had to communicate their ideas to the freshmen (non-technical audience) as the design work progressed. Freshmen were invited to attend planning meetings with the seniors, and so were able to observe the interaction that existed in technical meetings. In many cases, freshmen were present during much of the planning and design phases of the projects.

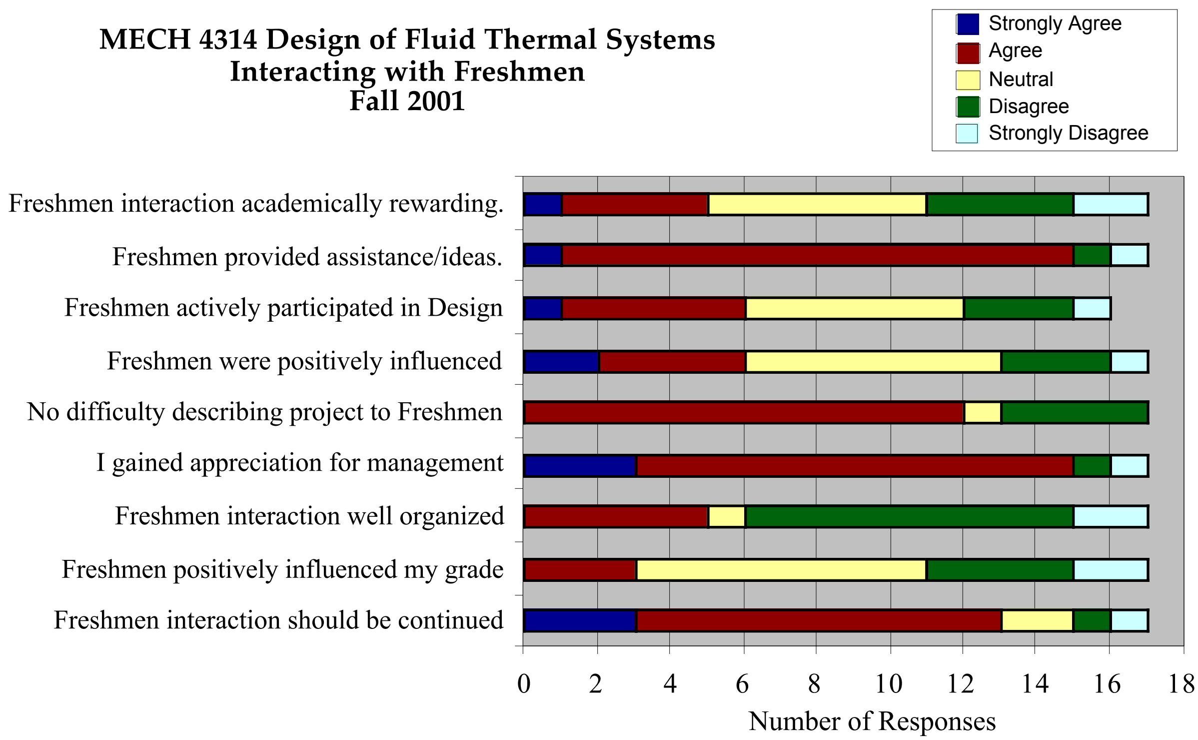
At the end of the semester, the freshmen were required to submit written reports describing their experience and to give oral reports to their classmates regarding the work that they had completed as co-ops. Freshmen were asked to describe the project they worked on, and explain how they contributed to its overall completion.

ASSESSMENT RESULTS

At the end of the Fall 2001 semester, the seniors were given assessment instruments in the form of a quantitative/qualitatively-based survey which measured results In the following areas:

- program objectives as related to ABET's "A-K"
- coverage of competency topics as compared to course objectives
- course management
- appropriateness/relevancy of pre-requisites
- progression of technical communication skills
- Interaction/experiences with freshman students

The focus here is on their opinions regarding their interaction with freshmen. Figure 1 displays graphically the seniors' responses. As indicated in the legend, a purple color means "Strongly Agree," a red color indicates "Agree," yellow means "Neutral," green signifies "Disagree," while cyan indicates "Strongly Disagree." The colors in the legend are arranged purple to cyan—top to bottom. In the chart, purple to cyan is arranged left to right. A preponderance of purple and red at the left edge is considered highly favorable.



(a) Interacting with the freshmen was an academically rewarding experience.
The response to **Item a** indicates that interacting with freshmen was not particularly rewarding for 6 out of 17 seniors, although 5 of 17 thought it was. Seniors in general did not feel that their grades were improved by the presence of freshmen on their design teams. (See Item h.)

(b) The freshmen were able to provide our group with assistance/ideas.
Despite the response to **Item a**, **Item b** shows that 15 of 17 seniors believed that freshmen were able to provide some assistance to the overall design effort. Every group was able to have the freshmen work with them in some capacity.

(c) The freshmen were able to participate actively in the design process.
Item c shows that freshmen participation in the actual design phase was rather limited, due to their inexperience with engineering fundamentals. It was, however, desired to have the freshmen gain an appreciation for engineering design.

(d) I believe I was able to positively influence the freshmen to want to stay in engineering.
One of the objectives of building this collaboration was a desire to increase the retention rate of the freshmen by involving them with the seniors in design work. **Item d** shows that the seniors

perceived that they had no positive influence on making freshmen want to stay in engineering. One interesting anomaly was noticed, however. A freshman working on the "Bad Guy's" Pond decided that engineering was not what he wanted to major in. He transferred into another college, yet found the project interesting enough to continue working on it with the seniors.

(e) I had no difficulty in describing our project to the freshmen.
Item e indicates that the seniors had little difficulty in describing their projects to the freshmen. Developing the student's ability to communicate technical ideas to a non-technical audience is one of the seldom mentioned objectives in this course.

(f) By working with freshmen, I gained some appreciation for the effort involved in managing engineers.
Item f shows that 15 of 17 seniors gained some appreciation for the effort involved in managing engineers.

(g) I thought that this entire exercise of involving freshmen in senior design projects was well organized.
The seniors felt that this venture was not well organized, as indicated in **Item g**, which is something that can occur with any new idea. In another part of the survey, several students made suggestions as to how to minimize some of the organizational problems encountered.

(h) Interacting with the freshmen has had a positive effect on my grade in this course.
Item h shows that interacting with the freshmen did not have a positive effect on the grades received by the seniors.

(i) The practice of using freshmen to interact with the senior design groups should be continued.
Item i asks the seniors about continuing the practice of involving freshmen in senior design projects, and the responses here were among the most positive in this portion of the survey. In the comments section, one senior wrote that interacting with freshmen was a good idea and should be continued.

In summary, the seniors appeared to view their experiences with the freshmen-senior collaboration experiment in a mildly positive light. The most positive response elicited by the survey indicates that the 15 of the 17 seniors believe the experience gave them some appreciation for the challenges faced by managers of technical projects. Close behind, 13 of 17 seniors believe the collaboration to have been a worthwhile experience and that it should improved, not scrapped. (It should be noted that the freshmen were also surveyed, but the results are not a part of this paper.)

CONCLUSIONS—LESSONS LEARNED / ACTIONS PLANNED

The survey instrument yielded information that will be applied to the freshmen-senior collaboration project. Discussions with seniors, freshmen, faculty provided additional data. Information gained from these sources should help to identify areas that need improvement; the process will be continued next time the senior design course is offered.

It was noted that the freshmen classes and the senior classes were offered at different times of the day, so there were problems in scheduling meetings in which freshmen and seniors could both attend conveniently. A group of seniors subsequently made very creative suggestions for eliminating this problem.

The responses to **Item h** shows that interacting with the freshmen did not have a positive effect on the grades received by the seniors. This does not mean it had a negative effect; only that the effect was not a positive one.

After both the Freshman and Senior courses were completed, and grades assigned, the faculty involved in this experience met to formalize their assessment of the freshmen-senior collaboration experiment and to plan accordingly for the future. Every faculty member was in agreement with the seniors that the experience was worthwhile and that the collaboration should be repeated in future offerings of these two courses.

It was also painfully clear that there is considerable room for improvement! Although a long list of lessons learned and specific actions to improve the experience was assembled, space limitations dictate discussion of only the two most salient lessons. First, the quality of the experience varied considerably from group to group. Clear definition of the ways that the freshmen and seniors interfaced should be distributed to all parties at the very beginning of the semester, and faculty must ensure compliance as the semester progresses. Second, although some interesting work was accomplished by almost all freshmen, as a whole they were not as involved in the design process as had been hoped. The task plan developed by the seniors must explicitly show a Preliminary Design Phase, with an anticipated completion date, in which the freshmen can actively participate in a meaningful way despite their limited technical expertise.

It is believed that implementation of these and other corrective actions will lead to a more rewarding experience for all involved in the Fall 2002 Freshman-Senior Design Collaboration.

BIBLIOGRAPHY

Some project titles, budget/bidding sheet, project management and other details were taken from *Design of Fluid Thermal Systems* by William S. Janna, Brooks/Cole Publishers, Monterey, CA, 1998.

See also: http://www.people.memphis.edu/~herffcoll/mech4314.html

BIOGRAPHICAL INFORMATION

John I. Hochstein—John I. Hochstein joined the faculty of The University of Memphis in 1991 and currently holds the position of Chair of the Department of Mechanical Engineering. In addition to engineering education, his research interests include simulation of micro gravity processes and computational modeling of fluid flows with free surfaces. He is a co-author of a textbook, *Fundamentals of Fluid Mechanics*, with P. Gerhart and R. Gross and is an Associate Fellow of AIAA. Dr. Hochstein received a B.E. degree from the Stevens Institute of Technology (1973), an M.S.M.E. degree from The Pennsylvania State University (1979), and a Ph.D. from The University of Akron (1984).

William S. Janna—William S. Janna joined the faculty of The University of Memphis in 1987 as Chair of the Department of Mechanical Engineering. He is currently Associate Dean for Graduate Studies and Research in the Herff College of Engineering. His research interests include boundary layer methods of solution for various

engineering problems, and modeling the melting of ice objects of various shapes. He is the author of three textbooks, a member of ASEE and of ASME. He teaches continuing education courses in the area of piping systems and in heat exchanger design and selection, for ASME. Dr. Janna received a B.S. degree, an M.S.M.E. and a Ph.D. from the University of Toledo.

<u>Hsiang H. Lin</u>—Hsiang H. Lin joined the faculty of The University of Memphis in 1985. His teaching and research interests include kinematics, dynamics, vibration, design, and optimization of mechanical systems. Dr. Lin received a B.S.M.E. degree from National Chung-Hsing University, and earned his M.S. and Ph.D. in Mechanical Engineering from the University of Cincinnati. He is a member of ASME and AGMA.

<u>Anna Phillips</u>—Anna Phillips is Director of Technical Communications at The University of Memphis in Memphis, Tennessee, and she's also an active instructor and researcher in the Civil Engineering Foundation sequence. She received her B.A. degree in English from Memphis State University, her M.A. in English from The University of Memphis, and is completing doctoral studies in Counseling, Educational Psychology and Research at The University of Memphis. Research interests include cognition and learning as applied to engineering education, team-teaching and multidisciplinary modes of instruction, and methods of assessment for engineering education.

APPENDIX: PROJECT DESCRIPTIONS

A "Bad Guy's" Pond†

Consider an evil character or "bad guy," so to speak. This person employs individuals who commit a multitude of crimes and he profits from their work. One employee fails to accomplish her assigned task, and the punishment is meted out by the Bad Guy. It is designed such that the employee will never fail again.

The employee is to give a report of his failure to the Bad Guy, and to get to the Bad Guy's office, the employee must walk on a pedestrian bridge that goes over a pond. While in the center of this bridge, the Bad Guy presses a button and the bridge itself collapses. The employee finds herself in the water where there are a number of flesh-eating fish (piranha, for example). In a very short time, the employee disappears from existence.

†Submitted by Professor Julie Mathis.

Determination of Valve Coefficient

Valves are used in piping system to control flow (on-off), or to control flow rate. Globe valves are good for controlling flow rate in a more precise way than ball valves, but globe valves cause a high pressure loss when place in a pipeline. Moreover, closing a globe valve from fully open requires turning its handle 7 or 8 revolutions.

Ball valves, on the other hand, have a very low loss coefficient, and they can be shut off with a 90° rotation of the valve handle. However, ball valves are not good for controlling flow rates.

There is always a question of how to size a valve. In industry, valves are sized by using what is known as a valve coefficient C_V, not to be confused with a venturi meter coefficient C_V. The valve coefficient is defined as the flow rate through the valve (expressed in gallons per minute, gpm) divided by the square root of the pressure drop (expressed in psi). The valve coefficient is to be obtained experimentally by setting up a flow system such that the pressure drop is 1 psi. The corresponding flow rate is then equal to the valve coefficient. This value is reported in catalogs and is designed to be used by engineers when sizing a valve for a system.

Clearly, the valve coefficient is not dimensionless, but instead has units of $\text{gpm}/\sqrt{\text{psi}}$. Although this is not academically acceptable, it is very useful when used as is.

Many ball valves have been tested to determine their valve coefficients, but limited testing has been done on three-way valves.

Flash Freezing of Chicken

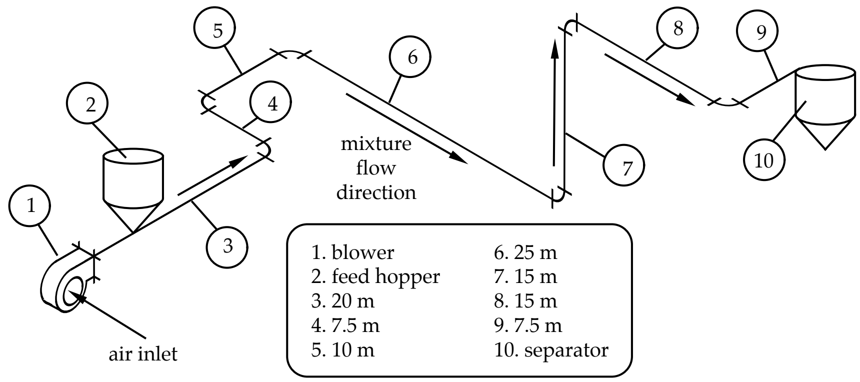
Freshly slaughtered chicken is cut up and stored in boxes that hold 40 lbs of chicken (gross weight). The chicken meat in the box must be frozen within 24 hours to meet FDA regulations, but the vendor wants them frozen overnight (i.e., within 16 hours), so they can be moved to a standard freezer. The freezer will maintain them at -20°F. A blast freezer is to be used for initial freezing. The boxes have tops so that they can be stacked.

Pneumatic Freight Pipeline

A freight pipeline involves the use of a fluid moving through a pipeline to transport a solid or a liquid substance over a certain distance; in other words, the moving fluid conveys "freight." The fluid itself in many cases is merely discharged at the destination.

Consider the freight pipeline sketched in Figure 10.18. At the inlet, air is moved into the pipeline by a blower. Just downstream is a hopper from which the substance to be conveyed is fed into the moving air stream. The mixture then flows through the pipeline until it encounters a separator. The air is discharged to the atmosphere, and the freight is collected at the bottom of the separator, where it can be discharged to a receiver tank.

The system of Figure 10.18 is to convey green peas to a packaging machine. Once packaged, the peas will be frozen and sent to market. The peas are to be conveyed at a rate of 3000 kg/hr, which is the maximum capacity of the packaging machine. The path to be followed is as indicated in the figure.



A freight pipeline using air to convey peas.

Fireplace Heat Recovery

Sheet metal fireplaces can be added to a room after the structure is built; that is, the fireplace need not be built when the home is. In order to enhance the usefulness of a sheet metal fireplace, it has been proposed to devise a means for recovering more of the heat that would ordinarily be discharged up the stack with the exhaust gases. It is believed that the most effective way to transfer more of the heat from combustion is by convection so that the air in the room is heated.