Longitudinal Design Teams: Students Teaching Students

Janet M. Rice
Department of Biomedical Engineering
The Johns Hopkins University
Baltimore, Maryland 21218
(410) 516-8482

jmrice@bme.jhu.edu

Robert H. Allen
Department of Biomedical Engineering
The Johns Hopkins University
Baltimore, Maryland 21218

Artin A. Shoukas
Department of Biomedical Engineering
The Johns Hopkins University
Baltimore, Maryland 21218

Abstract

We report on the characteristics of our year-long Longitudinal Design Team (LDT) courses, which have been taught since Fall 1998. Our main goal in these courses is to have teams of undergraduates at all educational levels work together solving problems that involve design in biomedical engineering.

Consisting of about ten students, each team is composed mostly of freshmen, who, with the help of upperclassmen mentors and an upperclassman Team Leader, are able to use the knowledge they have gained in their introductory courses and from their life experiences and apply it to biomedical engineering problems. In the Fall semester, teams work on one or two projects, where they design, perform, measure and apply principles of physics to develop an understanding of a bio-mechanical event. In the spring, teams work on individual design projects proposed by "customers." Faculty mentors interact with the team leaders and they decide how to proceed with their respective projects. Because the course is open to all educational levels, freshman students often reregister for the course as more upper level students. In addition to a learning environment, the design team is also a place for underclassmen to develop relationships with upperclassmen and vice versa. These relationships have proved particularly useful to the freshmen in choosing their courses, as well as in deciding summer and research plans. The upperclassmen are also learning how the knowledge they have gained in their coursework applies to solving practical problems. Although only in operation for three years, others perceive tangible results as well. In particular, the majority of customers are satisfied with the prototypes they receive. These preliminary results indicate that this unique program helps our students become acclimated to our curriculum and in preparing them for their profession.

Background

Within the last decade, engineering educators have realized that experiencing design as part of the undergraduate experience is crucial to learning design. Since the early 1970's, design courses have been an important part of engineering curriculum. [1][1] In his text, Ullman [2] observes that synthesis and experience are critical parts of the design process; much more so than analysis or re-analysis.

In the late 1990's, educators began to address the issues of teaching design to students during the freshmen year. Burton [3] gives four reasons for the importance of design: motivating students, promoting design concepts, encouraging teamwork, and introducing engineering tools, and describes eight different models currently being used. These models range from reverse engineering to case studies to full-scale projects.

This paper describes a new and unique model for introductory design education that involves teams of students where upper-class students mentor and guide freshmen as they solve engineering problems. Over the course of the year, the teams complete a small-scale mini-project, a moderate scale data-collection and analysis project, and a full-scale design project.

Purpose

The Longitudinal Design Teams were started to introduce freshmen to Biomedical Engineering, to foster mentoring relationships between students of various levels, to allow older students to apply what they've learned by teaching younger students, and to give all the students experience in leading or being part of a team.

History

The Longitudinal Design Teams began October 1998, with 2 teams and 27 students. The upperclassmen were recruited through email and an informational meeting. Each interested upperclassman completed an application that addressed the skills they would bring to the team, their interpersonal/teamwork skills, and their commitment to the team. Faculty screened these candidates, looking for traits—good academic standing, demonstrated interpersonal skills, leadership in nonacademic pursuits—which would make them good leaders in this course. Once the upperclassmen were chosen, they were responsible for selecting the freshmen for their team. Both teams of upperclassmen chose to interview the interested freshmen. Prior to the interviews, each freshman was asked to explain why he or she wanted to participate in the longitudinal design teams. The most commonly cited reasons were to have an early introduction to Biomedical Engineering (20/26), to gain practical experience (19/26), and to work in a

[1] Numbers in the brackets designate references at the end of the paper.

team setting with upperclassmen (13/26).

Once the teams were formed, they began meeting weekly to work on the design problem for that semester. The fall project involved determining the arterial blood pressure of one of the giraffes at the Baltimore Zoo. The students were given a value for the pressure at eye-level and were to calculate the pressure at heart-level. The only stipulation was that the students were not permitted to enter the enclosure the giraffe was housed in.

The teams decided amongst themselves which factors (pressure drop due to gravity according to Bernoulli's Law, pressure drop due to flow according to Hagen-Poiseuille's Law, etc) to include in their calculations. Each team then designed and built a device to measure the height and length of the giraffe neck and traveled to the Baltimore Zoo to take their measurements. After the zoo trips the teams analyzed their data, accounted for their error, and prepared their culminating presentation. Copies of these presentations are available on the world wide web in the departmental web site at: http://www.bme.jhu.edu/courses/580.111/pastprojects.htm. One of the team leaders also required the freshmen to submit a written report of the project.

Throughout the fall semester, the two teams met weekly to discuss the project, their progress, and the science involved. In addition the teams met in subgroups to work on various aspects of the project. The team leaders also met informally throughout the semester with each other and with the organizing faculty member.

The performance of the students was assessed by the senior team leaders and approved by the faculty member. Grades were based on participation at the team meetings and contributions to the overall project. Each student completed an evaluation of his or her teammates. These evaluations were reviewed by the senior team leaders and the faculty member and factored into the grades for the semester. After the grades were assigned, the students were given a summary of their evaluations so they could improve their personal performance. The faculty member assessed the senior team leaders' performance, which were based on their leadership of the teams.

At the end of the fall semester, the senior team leaders developed an evaluation form to assess the course. The course evaluation covered the actual project (understanding, interest level), team structure, teaching/being taught, senior leadership, and the overall experience. As a whole the students found the project to be interesting (26/26)[2] and understandable (24/26)[2]. All of the freshmen thought being taught by students was a positive experience (13/13)[3] and most of the upperclassmen had a positive experience teaching. (12/13)[3] Every student indicated that the overall experience was positive. (26/26)[2] In response to the question "What did you get out of the semester?," the most mentioned benefit from the freshmen was a better understanding of problem solving and engineering design (9/13). Other things the freshmen mentioned were a better understanding of Biomedical Engineering (3/13), skills in teamwork (3/13), and practical application of what they had been learning. (2/13) The upperclassmen responses included new friends (4/13), a better understanding of engineering design/ problem solving (3/13), skills in teaching (2/13), practical application of what they had learned (2/13), and skills in teamwork. (2/13)

The students were also asked what they would change if they were in charge of the course. The most mentioned changes were more time for the project (10/23), clearer instructions (7/23), more hands-on project (7/23), and more freshmen for the number of upperclassmen (5/23).

In the spring semester, the upperclassmen were given the freedom to develop a project for their team. By this point in the year, they know the interests and strengths of their teams and can choose a project that matches well with their team. After one semester the team leader and upperclassmen have established a structure and expectations for the team, and can devote time and energy to developing their own project. One of the teams chose to design and build a proto-type for an artificial arm. The other team set out to determine the "best" seat in Shriver Hall, the main campus auditorium. Both teams developed the design specifications, project timeline, and evaluation standards.

The team that designed the arm started with a "Captain Hook" model of a stub with a hook on the end. Starting with this model, the freshmen researched the current technology for

[2] Students who rated the course between 7 and 10 on a scale of 1-10

[3] Positive, negative and neutral were determined from their anecdotal responses to the questions "What are your thoughts on teaching/being taught by students?"

artificial limbs, met with a double amputee to discuss his prostheses, and visited a prosthetic manufacturer. Their final arm began just below the elbow and included rotational movement at the wrist and grasp at the hand. The "fingers" were connected via cable to a shoulder harness and opened and closed as the patient shrugged his or her shoulders. The wrist rotates as the patient extends or flexes his or her elbow.

The team that studied the sound waves in the auditorium started with a single source. They assumed symmetrical reflection, no absorption at the walls, and complete absorption at the ceiling. Their solution examined the collective magnitude of the sound waves at locations throughout the auditorium.

As with the first semester, the freshmen shared their projects with their classmates and the Biomedical Engineering faculty. They also evaluated the course and their teammates.

Current Status

The Longitudinal Design Teams are now in their third year. Currently 51 freshmen, 15 sophomores, 31 juniors and 11 seniors are involved in the 10 design teams. Each team has one senior team leader or two junior co-leaders. Two faculty members and a course coordinator support the course.

The upperclassmen register for the course in the spring and the freshmen register during July. Prior to the start of the school year, the course coordinator assigns the students to their teams in the following order. First, the team leaders are chosen based on good academic standing, demonstrated interpersonal skills and leadership in nonacademic pursuits. Then the remaining upperclassmen are distributed amongst the teams so that each team has a distribution of engineering concentrations (mechanical, electrical, chemical, etc), academic years, and design team experience. Once the upperclassmen are selected, the freshmen are distributed. Before students enroll at Hopkins, they complete an advising profile that includes questions on their non-academic interests. These sheets are used to place the freshmen on teams with upperclassmen who have similar interests.

The students are introduced to one another and to the basic structure of the course at an introductory meeting during the first week of classes. After this initial meeting, teams meet amongst themselves for the remainder of the semester. Student team meetings are an opportunity for the upperclassmen to teach the freshmen the background for the projects, for the team leader to pass on any administrative information, and for the team to discuss the status of their project. The meetings usually last one hour, and are held at a time and place that is convenient to the students involved.

The team leaders meet weekly with the faculty, and coordinator. This meeting is a time for the team leaders to share with one another the difficulties they are encountering with their team or the problem. These meetings also provide training for the team leaders in leadership and in the background for the project. Finally, administrative and logistics information is given to the team leaders as these meetings.

For academic year 2000-2001, the teams address three projects: a month-long mini-project in September, a uniform fall project, and a team-specific spring project.

The purpose of the mini-project is to have students learn to interact with one another to solve a given problem and to facilitate an early sense of team spirit. It takes place over a short time so the students are forced to begin working together very quickly. The initial project also contributes to an early sense of accomplishment and team unity, which result in improved performance on the later projects. At the end of the mini-project each team demonstrated their product to the rest of the course.

The Fall 2000 Mini-Project was to design and build four devices to move a ping pong ball around a square. The faculty official placed the ball in the playing device of the first team member. The ball then traveled from player to player around the course two times, during which time the teams were subject to five rules. 1. Each player must stand in one place while the ball is in play. 2. Neither the device nor the ball may touch the floor. 3. Team member's hands may not touch the ball. 4. The functioning of the devices on each leg of the square shall be different. 5. No square may be smaller than 3 m on each side. The teams were limited to the following materials: foam core, rubber bands, construction paper, wood dowel, and white or hot melt glue.

The main fall project is the same for all the teams and it lasts approximately 2½ months. Having a uniform project allows the team leaders to better help one another with the project. We have also found that the seniors need some time to adjust to the freedom and responsibility this course requires. Most of them keep expecting the faculty and course coordinator to tell them how to lead their team or how to go about solving the problem. By having a uniform

problem for the fall, the team leaders are relieved of some organizational work while they are adjusting to their roles. Typically this project has focused more on analyzing data that was collected than on engineering design. The fall project concludes with a 10 minute oral presentation from 1 or 2 freshmen, and a written report. These presentations are given the last week of the semester to parents, faculty, and fellow students at the Biomedical Engineering Freshmen Design Day.

For the Fall 2000 Main Project, students used first year physics and calculus to calculate the G forces on a subject riding a roller coaster. They then compared these forces to actual measured ones. The students developed appropriate models to determine the effects of the G forces on arterial pressure. One student per team was fitted with a Holter monitor to measure the actual heart rate changes that occur with each ride. The Joint Committee on Clinical Investigation of the Johns Hopkins University School of Medicine has approved this study.

Towards the end of the fall semester, the teams review the list of possible topics for the spring project and submit their top choices. These projects were solicited from contacts throughout the university, the local community, and industry. Problems are selected that reside at the interface between medicine and engineering, and that could benefit from a design solution. All submissions are posed in the form of a problem statement. If a team selects the project, the proposer or customer of the project becomes the team mentor and works with the students to a final solution and/or product. In the event that the proposer does not have an engineering background then a faculty volunteer is solicited to act as the mentor. A voluntary $500 administrative fee is requested from the proposer of the project. The results from the spring project are presented at the end of the semester to the faculty, proposers, and students within the course.

A partial list of spring projects is included in

Table 1 shown below.

Table 1 – Some Past Spring Projects

Year	Project	Sponsor
1999	Acoustics of Shriver Auditorium	Team Sponsored
1999	Prosthetic Arm	Team Sponsored
2000	EMG Controlled Car	Team Sponsored
2000	Design of a Novel Apparatus to Study Mass Flux of Water and Dissolved Solvents through the Endothelial Cell Barrier	Randall Dull, Assistant Professor, Johns Hopkins University School of Medicine, Department of Anesthesiology
2000	First Alert Shirt	Team Sponsored
2000	Techniques to Minimize Thromboembolism on Mechanical Heart Valves	Artin Shoukas, Professor, Johns Hopkins University, Department of Biomedical Engineering
2001	Weight Bearing Sensor and Alarm	Samuel Esterson, PT, Clinical Director, Physiotherapy Associates, Baltimore, MD
2001	One Arm Bike Handle	Sharon Gavagan, Mother of Physically Disabled Child
2001	Microindenter Development	Brent Parks, Director, Biomechanics Research Laboratory, Union Memorial Hospital, Baltimore, MD

Evaluation of Students

We have slightly altered the grading schema since the first year to incorporate a measure of the project quality, instead of just individual contributions. Students still complete the peer evaluations for their teammates as previously and the team leaders submit lists of grades for the team. In addition, during each of

the presentation times (mini-project, fall project, spring project), the team leaders, faculty, and coordinator evaluate the projects and presentations. These grades are averaged and the team average is factored into the individual grade the team leader assigned. Giving the team leaders responsibility in determining their team members' grades and in evaluating the other teams has caused the team leaders to take more ownership and responsibility in the course. As before, the team leaders are graded by the faculty and coordinator based by their team members' evaluations of them, the quality of their team project, their participation in the team leaders meetings, and overall leadership of their team.

Social Components

One of the initial goals of the course and of the freshmen that joined the course involved the social aspects. The goals were for the freshmen to meet upperclassmen and for the upperclassmen to have the opportunity to mentor younger students. These relationships go beyond the academic issues associated with the project. Most of the students became friends with one another (24/26 in 98-99, 65/67 in 99-00), and some teams have even had reunions after the year ended. We have found this social component to be very critical to the success of the team.

Evaluations

We evaluate this course on the basis of student evaluations, alumni evaluations, project quality, sponsor feedback, and our general impressions. Table 2 contains a summary of the student evaluations. As a whole, students felt that it was a positive experience to have students teaching other students. They also felt like the course improved their communication, teamwork, and design skills. Overall, the students felt it was a positive experience. Table 3 summarizes their responses to the question, "What did you get out of the project?" Some anecdotal responses from the student evaluations are included in Table 4 through Table 7.

Table 2 - Summary of Student Evaluations[4]

	1998-1999	1999-2000	2000-2001
Teaching was a Positive Experience[3]	12/13	32/33	47/48
Being Taught by Students was a Positive Experience[3]	13/13	24/35	34/38
Positive Overall Experience[2]	26/26	63/67	76/88
Improved Communication Skills[2]		55/64	69/88
Improved Teamwork Skills[2]		62/64	77/89
Improved Engineering Design Skills[2]		59/64	66/85
Became friends with the upperclassmen/freshmen	24/26	65/67	

Table 3 - What did you get out of this project?

	Freshmen		Upperclassmen	
	98-99	00-01	98-99	00-01
Better understanding of problem solving/design	9/13	7/35	3/13	9/31
Better understanding of BME	3/13	3/35	1/13	2/31
Teamwork Skills	3/13	9/35	2/13	15/31
Friends	1/13	5/35	4/13	5/31

[4] Blank spaces in the table indicate that question wasn't asked on those evaluations

Teaching Skills		2/13	6/31
Science Knowledge	12/35		8/31

Table 4 - What are your thoughts on teaching younger students?

What are your thoughts on teaching younger students?
▪ I love it! It's hard and sometimes frustrating, but to see them understand something is rewarding.
▪ I think it was a good experience. You get to see how people actually think – not just how they solv scripted problem for a class.
▪ I love it! Really though, the open, team structure allowed both freshmen and upperclassmen to learn a teach one another.
▪ I think that longitudinal design is a fantastic was for young BME's to learn about their future major and for the elders, to learn from them.
▪ I think that it is useful for freshmen students to have this kind of interaction with upperclassmen. It helps teach them what kind of effort and responsibility is needed for university level study. That is the teacher won't do all the thinking for you
▪ I think it helped me (the teacher) as much as the younger students because it forced me to synthesize wha have only recently learned, to extract the essential part of the material and explain it in intuitive fashion.
▪ It's an amazing learning experience. It really forces you to understand the material perfectly before you e start to say a word to them
▪ I think it is the most rewarding experience a person could have and it should be something that upperclassmen have the opportunity to do

Table 5 - What are your thoughts on being taught by older students?

What are your thoughts on being taught by older students?
▪ Team mentors did a great job. If the other student mentors do half as well as them, then this design te project will be a great success
▪ I think it is very effective for first year BME students to be taught by older BME students. It gives students a more comfortable environment that is not totally formal, and helps them interact with others as teammates, students, and friends.
▪ I enjoy being taught by older students – in our group they are all more than competent
▪ There's a sense of camaraderie and closeness that one would never get if the teacher was an adult. The inn respect for elders was still there, but because there was such intense empathy from the older students about the ordeals of the freshmen experience, it was a delightful blend of respect and family bonding.
▪ They knew what they were doing and took the job seriously. I had a very wonderful experience, and thou of this as my favorite class where I learned a lot and had the most fun.
▪ They were pretty effective in helping lead and guide us in our project. They told us what we needed to kn and gave us enough room to go solve problems ourselves.

Long Term Benefits

Of the 27 students who participated in the inaugural year, 19 continued until they graduated, or are presently in the course, 4 are no longer in the department, 2 did not have the time for the course, 1 felt it was mismanaged, and 1 felt he could better use his time elsewhere. Those that remained did so because they enjoy the teamwork, practical applications, and leadership experience. One student commented, "BME Design Team offers the entirely unique opportunity to work cooperatively with reliance on the skills and talents of fellow students, and this is something I have wanted to take advantage of during these past years."

I (Janet Rice) can also attest to the long term benefits of this course. I was one of the two team leaders the inauguration year of the course, and presently I am the course coordinator. Being a team leader was a

wonderful experience. I learned many things about leadership, organization, and team management. I learned how to structure the team and upperclassmen so that everyone learned, everyone had fun, and the project was accomplished.

Conclusions

In conclusion, we believe that the Longitudinal Design Teams is an effective model for design education. Freshmen become excited about engineering, familiar with the design process, experienced at working in a team setting, and connected to upperclassmen. Upperclassmen learn to apply what they've studied, to communicate information in a way that freshmen can understand, to lead students of various levels so that a quality product results, and to walk the line between being a peer and an authority figure.

Table 6 - What did you get out of this course?

What did you get out of this course?
▪ I gained a better understanding of an engineer's mind set, new problem solving approaches, research ide and may even a few new friends.
▪ Applying concepts, calculations, and just pure creativeness to create a work of art
▪ A great sense of some BME related projects, knowledge of the program and leadership, friendship fr upperclassmen, as well as fellow freshmen, and excitement to go on with BME and learn more things
▪ I feel the most important thing that I got out of the project was insight into the workings of a team accomplish a common goal
▪ The most beneficial thing I obtained was contacts. Now I have seniors I can look to for advice and help
▪ How to convey my feelings about aspects of the project that were contradictory to other people's opini without hurting anybody's feelings
▪ I learned how important it is to work with members of a team. I had to make some sacrifices, but it was the better.
▪ An experience in leadership skills and how to work with people's skills and delegate responsibilities
▪ Where do I start? I learned so much about being a leader – especially that confidence and organization crucial. I got to reinforce the skills I've learned in various classes. I was able to share my knowledge with younger students.
▪ I learned how to deal with situations that don't go as expected, be flexible, be organized, be clear, and be fi
▪ I now have a whole different outlook on the heart and it's function
▪ I learned a lot about engineering design, learned what BME's do when they graduate, and made friends w the upperclassmen
▪ I've learned how to more effectively lead my peers and facilitate communication between the team member
▪ Useful sense of teamwork and leadership skills. I will never forget my experience as a team leader
▪ Leadership, communication, interpersonal, problem-solving, and engineering skills. Lots of good stuff th will carry with me through life

Table 7 - Other Comments

Other comments
▪ A large positive is that all the team leaders learned how to rely on one another. It was almost as if I ha team leaders "team" and then my own team that I worked with all semester.
▪ I spoke with some of the parents at the presentations, and they were so proud that their child could involved in something so big even though they were only freshmen.
▪ I wish I had been part of this team as a freshman, as I feel that it is a wonderful way to introduce them to field of BME and also to get them excited about the work yet to come

- [Can you talk to the upper classmen about non-project topics?] ABSOLUTELY!!! This was the best part the design team.
- I found the design team a very good way to establish connections with upperclassmen who had already b through the different aspects of the BME program.
- I can't express how great this has been. It really made my semester to have this class, the leadersh friendship, and discovery of knowledge all in one. Thank you for that opportunity.
- Our group worked much better as we got to know each other

1 "39th Annual Report, Year Ending September 30, 1971," Engineers Council for Professional Development, 345 East 47th Street, New York, 1971.

2 Ullman, D. G. 1992, *Mechanical Design Process*, McGraw Hill.

3 Burton J, and D White, "Selecting a Model for Freshmen Engineering Design" *Journal of Engineering Education*, July 1999, 327-332.

Review of "Longitudinal Design Teams" by Rice et al

Comments for Conference Organisers

This paper describes courses at John Hopkins University that involve freshmen students working with upperclassmen in joint projects on biomedical topics. I found it an interesting and exciting paper, and recommend that it should be accepted as it stands, subject to reformatting and to the minor changes suggested overleaf.

Review of "Longitudinal Design Teams" by Rice et al

Comments for Authors

This paper gives a very readable description of the "Longitudinal Design Team" course in Biomedical Engineering at JHU. I found the paper very readable, and am very interested, even excited by what the authors describe. I hope that we may be able to adopt some of their ideas and experience in my institution. My only suggestions for change, other than reformatting the paper to the correct format for the conference, are as follows:

- Provide more information about how the course fits in with other courses that the students have - course load and weighting etc.
- There is no need to say in a footnote that parentheses indicate references

Longitudinal Design Teams: Students Teaching Students
Rice, Allen and Shoukas

Recommendation: Accept with modifications

The paper is a description of a method of teaching design used since 1998 at Johns Hopkins University, Baltimore. The paper describes the process, developments, student feedback and informal analysis

The paper would make for interesting discussion in the International Comparisons in Design Education track.

The authors should make the following changes before publication:

- Typesetting of pages 6 onwards.
- Comments on the method of awarding individuals marks in the team project
- More critical analysis of the class (what didn't the students like about the project, have the teaching staff got any concerns?)