

Biomedical Engineering Senior Capstone Research at the University of Hartford

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Abstract:

Graduating biomedical engineers often work along side medical professionals with little engineering background and must be able to communicate technical issues clearly. With these issues in mind, we decided that all our students should have the experience of working in clinically-based research laboratories in the local area or near the students' homes.

With the assistance of a faculty advisor, each student sought a laboratory in his/her area of interest. The research is structured as two course equivalents (100 hours each). "Biomedical Engineering Capstone Research I" was designed to immerse the student in a wide range of laboratory functions. "Biomedical Engineering Capstone Research II" is designed to give the student in-depth experience by functioning as an engineer on a project, either ongoing in the laboratory or being developed.

Grading of each course is via written and oral reports, as well as laboratory supervisor input. The first course requires the writing of a report on the experience, while the second requires a formal research paper in the style of journal articles.

The experience from these courses has been excellent for both the students and the program. Project areas have included: dental mechanics, computer modeling, wrist motion analysis, and gait analysis. These projects often led to professional meeting presentations and journal articles. The bulk of the supervisor reports have been excellent, and even led to funding for a master's degree.

Another important outcome from this capstone research is a method of outcome assessment. Outcomes are of great importance for ABET 2000, and the concept of an external researcher reviewing a senior level student is very useful. The students are able to utilize their engineering education prior to graduation and assist in the "cutting-edge" of biomedical research. Feedback from the students and supervisors allows us to modify our course content to maintain currency in our curriculum.

1. Introduction:

As the undergraduate program in Biomedical Engineering was developed at the University of Hartford, a desire was expressed to present the students with the opportunity to understand the

requirements of performing research “in the field”. After examining the more usual internship programs, we decided to develop two senior courses to allow students to utilize the skills derived from both their biomedical engineering and general engineering courses. These courses purposely send the student off-campus to work in clinically-based research laboratories. This sequence of courses assists in the senior capstone engineering research and design experience, which is an important aspect of ABET 2000.

Our program is a mechanically oriented one, being originally developed from the Mechanical Engineering structures track. The students first receive basic engineering knowledge, including statics, dynamics, mechanics of materials (including a laboratory course), basic electrical engineering, electronics, thermodynamics and fluids. The core Biomedical Engineering courses build upon these fundamentals with specific courses in Biomechanics, Biofluids, and Bioinstrumentation, resulting in strong engineering depth. During the Sophomore and Junior years the students also take two terms of Biomedical Engineering Seminar, where they are introduced to the variety of options within the field and have numerous discussions with members of the clinical and research medical community. The courses and talks present the students with some of the options that they might wish to pursue during their two capstone courses.

2. Capstone Research Objectives:

The two capstone courses were designed to satisfy numerous objectives, both from the viewpoint of the program and the student. These objectives are always being updated and refined, as noted later in this paper.

The first general objective is to allow the student to interact with future work partners. This exposes the engineering student to the multidisciplinary approach required to combine engineering and medicine. By working with non-engineering medical professionals, the student begins to understand how to communicate effectively with those who do not have the same educational background. These people have diverse viewpoints and approaches from those usually associated with classical engineering projects.

A second general objective is to give the student a chance to evaluate future employment directions in research, industry and graduate studies. By working in a clinically-based setting, the student has an opportunity to determine if this path is the correct one for them. The student also obtains a grasp of what is required to pursue a career in that particular area. Can one start work directly, or does one need further education? Is this a focus more conducive to the research laboratory or industry?

A third general objective is to evaluate the student’s preparation. The papers written as part of each course give evidence as to the student’s preparation. Feedback from each research advisor (at the laboratory site) helps to evaluate both the individual student and the program's ability to prepare the student scholastically. This evaluation is important as part of the senior year experience for ABET 2000 goals, as these courses form a capstone for the basic engineering and biomedical engineering educational experience.

A fourth general objective is from the student's perspective. The courses build a student's confidence in their ability to function as engineers in the multidisciplinary field which is biomedical engineering. The student obtains experience which can be placed in their resume, and write reports that may be included in a student's portfolio (which displays samples of their work).

3. Course Architecture:

The senior capstone research experience is separated into two courses. The first is similar to internships where a student participates in the general activity of a laboratory, and becomes familiar with the daily requirements of research. During this time, many students become interested in a specific project, which may be used in the second capstone research course. The second course is designed to allow the student to act as an engineer on a project, or a portion of a project, of interest to the laboratory director. Each course requires approximately 100 hours of work by the student. Individual course specifics are noted below.

Both Capstone Research I and II are designed to send the student off-campus for a variety of reasons. First, we wished to present the students with a wider range of opportunities than can be found at a small school such as ours. Second, we feel that experiences outside the home university present a more diverse viewpoint than can be obtained by performing research onsite (for a similar reason that sabbaticals are often taken off campus). A clinically-based laboratory will address current clinical issues in a manner more difficult for an engineering laboratory (which has a different focus). Finally, these courses are a powerful means by which to obtain an external assessment of a specific student and the program in general.

Both Capstone Research I and II share many of the same procedures. In both courses, the student selects a potential research site (with the aid of the faculty advisor if required). This site may be near the university, the student's permanent address, or any other site of interest. The student makes the initial contact with the potential research advisor (laboratory director or supervisor). The faculty advisor then contacts the potential research advisor and discusses the course requirements and expectations. As noted above, each course expects 100 hours of work by the student, although more is often the case. There is no payment expected, although the advisor is free to discuss payment for additional work. For each course, the student maintains a daily written log and is expected to demonstrate professional behavior as expected by both a laboratory researcher and a graduate engineer.

The university faculty advisor evaluates and approves each student's site and project. This advisor monitors progress and work quality via discussions with both the student and research advisor. The faculty advisor also reviews the log and written portions of the courses, and assigns a grade with input from the research advisor.

The on-site research advisor directs the student's activities on a daily basis. This advisor provides both supervision and support for the student. The research advisor's assessment of the student's behavior and work is factored into the grading for each course. In addition, the feedback from the research advisor is used to evaluate and improve the courses.

Capstone Research I is designed to give the student a general overview of life in a clinically-based research environment. The student may participate in one or more projects, and may have to assist in such mundane procedures as laboratory clean-up and literature searches. Along with the daily log, the student is required to write a paper describing their experience. This paper summarizes activities, and discusses the positive and negative aspects of the experience. Suggestions for future course improvement are also placed in this report.

Capstone Research II is designed to allow the student to function as an engineer on a project of interest to both the student and the research advisor. This may include prototyping a project of mutual interest, working on a small aspect of a larger project, or participating as a team member on part of a long-term study. The actual project is to be agreed upon by the research advisor, faculty advisor, and student. Along with the daily log, the student is required to write a formal “journal style” report as the final part of this course. Although some of the projects have led to journal publications or professional conference presentations, this is not a requirement of the course. What is required is that in the final report the standard sections of a journal article (including abstract, introduction, methods, results, discussion and conclusions, references) are included.

4. Ongoing Course Modifications:

As noted in the above sections, this course is constantly being upgraded in part via the input of the research advisors and students. Changes to date include the formal documentation of expectation from each of the three participants (research and faculty advisors and student). An outcome sheet is being developed which will include the project title, site, participants, abstract, and a checklist for design and statistical aspects of the course. The first course (Capstone Research I) has been modified to allow students to work outside a laboratory setting. A number of students have requested the opportunity to work in the Clinical Engineering Department of hospitals, or (in a few cases) in industry. The Biomedical Engineering faculty decided that, if the faculty advisor approves the work, that these sites would be acceptable for Capstone Research I credit. The requirements for Capstone Research II remain as before, requiring that the student work in a clinically-based research laboratory. Finally, in keeping with ABET 2000 guidelines, future improvements to the Capstone Research Courses will require that research projects include a defined and substantial engineering design experience.

5. Selected Research Topics and Facilities:

As noted above, students may work locally or near their homes. As such, research sites have included a variety of laboratories at the University of Connecticut Health Center, Connecticut Children’s Medical Center, Hartford Hospital, SUNY Upstate Medical Center, Stony Brook and the University of Rochester. Capstone Research II report titles include: “Reinforcement of Dental Composites”, “F-SCAN Pressure Pad Sealing”, “Hand-Wrist Range of Motion Studies for Activities of Daily Living”, “Effect of Lead on Osteoporosis”, “Hip Implant – Bone Relative Motion Analysis”, and “Design of Astronaut Tools”.

6. Conclusions:

As noted in the previous section, there is a wide selection of research topics pursued by our senior students. This breadth of activity would not be possible in on-campus research for a small university.

The Capstone Research I and II courses are a powerful means by which to prepare a student for life after graduation, as well as a means of evaluating and improving the program. These courses are expected to constantly evolve as the needs of the profession and the students change. These courses have been found to be very successful to date, both for the students and the external research facilities. These are courses that students look forward to with anticipation, as have the external research advisors.

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