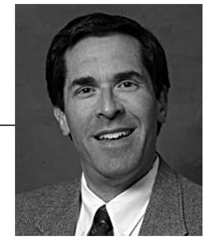
Senior Design

organizational support for senior capstone design courses



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The goal of any engineering program should be to prepare students for their professional and personal lives after graduation. For biomedical engineers, this could include a career in biomedical engineering, medicine, law, business, or another discipline. Since most of our graduates eventually work in industry at some point in their careers, the goal of biomedical engineering programs should be to produce graduates who are ready to function as biomedical engineers in industry with little additional training. Graduates should 1) know how to develop and commercialize a new product; 2) understand the technical, economic, legal, regulatory, and environmental constraints of medical device design; 3) effectively function on a multidisciplinary team; and 4) apply the necessary skills and knowledge toward the design and development of solutions that meet customer needs.

The senior capstone design course is the most important component of an engineering design program and plays an important role in the creation of biomedical engineers who begin their careers with the skills and knowledge needed to be successful in a short period of time. In my opinion, it is perhaps the most important course our senior biomedical engineering students will take in their undergraduate programs. No other course provides them with the opportunity to apply all that they have learned during the previous three years or more and develop the variety of skills needed for successful careers in engineering. The learning objectives for capstone design courses typically include providing students with the opportunity to 1) learn about the product development process and project management, 2) learn to solve open-ended problems with many "correct" answers, 3) develop their written and verbal communication skills, and 4) develop their teamwork and interpersonal skills through a team-based project experience. To meet these objectives, support from the biomedical engineering department (chair and faculty), the college of engineering administration, and industry partners is necessary.

A successful biomedical engineering senior design course requires a dedicated instructor who understands and has experience with engineering design, project management, and the product development process used in the medical device industry today. Ideally, the instructor would have some amount of experience in the medical device industry to share with students and guide his/her teaching.

In courses involving many projects, one instructor cannot effectively advise all project teams. In this case, additional faculty members with the required technical expertise for a particular project are needed to advise project teams. For this arrangement to be effective, the department chair and faculty project advisors must 1) recognize the importance of the capstone design experience in helping prepare students for careers in biomedical engineering, 2) support the goals of the course, 3) become familiar with the medical device design and product development process, and 4) be willing to commit their time to advising student project teams. In some departments where it is assumed that all faculty members will advise a project team, faculty members consider project advising as part of their jobs and volunteer advisors are easy to find. In other departments, the department chair might need to provide incentives, such as additional salary or credit toward a reduced teaching load to get faculty members to advise projects teams. Junior faculty working toward tenure may not want to spend time advising project teams if this activity does not count toward the requirements for tenure. In this case, allowing time spent advising project teams to count toward the requirements for tenure could help get more junior faculty involved. In addition to providing the human resources needed to advise project teams, departments should provide the financial resources needed to manage the senior capstone design course. This could include salaries for support staff, honoraria for guest speakers, and money for teams to build and test prototypes (especially for teams without industry sponsors who would normally provide resources for these activities). Creation and maintenance of a library containing up-to-date industry standards would also be extremely helpful to student design projects.

The college of engineering needs to provide support that the departments may not be able to provide. For example, additional funds could be made available for project teams as well as the resources needed to construct and test prototypes such as a machine shop, prototyping facilities, and test equipment. The dean of the college must be supportive of the goals of the design program and the capstone design course. He/she must find ways to reward faculty for participating in the course as project advisors. For capstone design courses involving students from several engineering disciplines (biomedical, electrical, mechanical, etc.), the college of engineering should also provide adequate staff for managing the course as well as funding for guest speaker honoraria and college-wide design competitions. The university administration can support design projects by providing a responsive Institutional Review Board (IRB) to expedite projects involving human testing and establishing a faculty- and industry-friendly intellectual property policy.

Support from other programs in other colleges within the university is needed for senior capstone design courses that include entrepreneurship as an important component. To create truly multidisciplinary entrepreneurial project teams consisting of students from other colleges such as business, arts and

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sciences, law, fine arts, and dentistry, medicine, physical therapy, or nursing, incentives to encourage students (and faculty) from these different programs to work together on projects must be provided. Requiring participation or offering elective credit for participation in the senior capstone design course can help get more students from other disciplines involved in design projects.

Support from industry partners is needed to maintain a successful senior capstone design course. The benefits of industry involvement in capstone design courses have been previously described [1]. Support can be in the form of guest speakers, project sponsors and advisors, and curriculum advisors. Guest speakers currently working for medical device companies can provide up-to-date treatments of various topics of importance to the medical device industry. Engineers from medical device companies can sponsor design projects and advise project teams on technical and other issues. Industry sponsorship typically includes providing technical advice and the resources needed to build and test prototypes. Working engineers can advise biomedical engineering departments on the components of the senior capstone design course as well as the entire biomedical engineering curriculum, helping to ensure that they remain relevant and up-to-date.

Creating a culture of design throughout all four years of the biomedical engineering curriculum is an excellent way to prepare students for a successful capstone design experience and support the course. This can be done by modifying some existing courses to provide additional opportunities for students to solve open-ended problems and develop their communication, interpersonal, and design skills in courses throughout the 4-year curriculum instead of only the senior capstone design course. Course modifications could include adding assignments or classroom activities that would require students to 1) complete group projects, 2) speak in front of groups, 3) write technical reports and other documents, 4) complete design projects (team or individual), and 5) compete in design competitions contained within a particular course. If only one of each of these modifications is made to each of a few courses in the biomedical engineering curriculum, students would benefit from the additional opportunities to further develop their skills and would be better prepared for the senior capstone course and beyond. By including a design project in courses offered during the freshman, sophomore, and junior years, biomedical engineering design programs can create a 4-year design curriculum. Sponsoring departmental or college of engineering design competitions, creating a senior design project public showcase event, and providing resources for nonproject-related design activities (that would allow students to "tinker" with some of their own ideas not related to any course or course related project) are additional ways to help create a culture of design.

In summary, a senior capstone biomedical engineering design course needs support from the biomedical engineering department chair and faculty, the college of engineering administration, other colleges within the university, and industry partners to help produce students who are ready to be productive engineers in industry. This support includes leadership, intra- and interdepartmental cooperation, project team mentorship, faculty incentives, financial and technical resources, and the creation of a culture of design within the engineering curriculum.

References

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Retrospectroscope (continued from page 75)

died. This event prompted Lillihei to seek Bakken's help to create a battery-operated pacemaker. Fortunately Bakken's Medtronic Inc. was in existence and Bakken designed and built the first "little white box"; Lillihei ordered five more. Word spread and Medtronic built more, and it is still building the (improved) 5800 and much more sophisticated pacemakers along with other medical devices.

The Bakken external pacemaker (the little white box) was designed for use with a direct-heart and a skin-surface electrode. The output circuit simulates a constant-current device in that the output current did not depend on electrode-subject impedance. The case had two chrome-plated handles that were used to hold the little white box to the chest with a band. A 9-W battery powered the pacemaker. A neon lamp (NE2) flashed with every pacing stimulus. The rate and output knobs were recessed to prevent accidental changing of the settings. The pacemaker was described by Lillihei's paper in *Archives of Surgery* (1957).

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