

Notes from DESIGN and INNOVATION Workshops

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Participants in the March 2005 BME Educational Summit sponsored by the Whitaker Foundation selected workshops designed to stimulate constructive discussion. One of these workshops focused on “Design and Innovation” within the BME curriculum. These workshops were well attended and characterized by high levels of interest and engagement. Workshop facilitators began the workshops by briefly reviewing highlights from the whitepaper that had been posted on the Whitaker website prior to the meeting. The goals of the workshops were to 1) identify novel and useful curricular practices, 2) raise awareness of challenges to be addressed and 3) identify opportunities for collaborative approaches. Several topics were introduced and general interest levels were assessed by a simple unblinded voting methodology. These topics were 1) Course Faculty, 2) Composition of Teams, 3) Intellectual Property, 4) Teaching of Process vs. Content, 5) Design in a Research Setting, 6) Graduate Student Design Education and 7) Entrepreneurship. Participants were encouraged to introduce and elaborate other topics of special interest. Topics with highest levels of interest were selected and 2-3 breakout groups were formed in each workshop session to create an environment more conducive to expression of individual opinions related to specific questions posed by the facilitators. Several topics emerged from the discussions within smaller breakout groups. We have attempted to capture the main points in the following summaries.

Source of Design Projects and Advisors

The group rapidly determined that many different versions of the design experience have been formulated by BME programs. Without formal quantitative assessment, it seems impossible to definitively state the benefits of one design program over another. Instead, each possesses strengths and weaknesses that should be addressed as programs evolve.

Project Generation and Selection

All participants agreed that projects should be based on specific needs that can be addressed through application of technology. Needs can be identified by students, faculty, external advisors, or clients within or outside the university. Most participants favored the prospective formulation of a master list of projects that were collected and qualified by faculty and industrial advisors prior to presentation to students. Still, some programs support and encourage students to identify needs and select project concepts after consulting with faculty and sponsor/clients. There was a strong consensus of opinion that students perform best when there are academically prepared for and are personally interested in their capstone design project. While some programs do not make special efforts to match skills and interests of individual students with projects, others coordinate skills and interests and serve as “matchmakers” in the project selection process so that students are more likely to be actively engaged and enjoy their design experience. The list of potential projects can be expanded by requesting project ideas

from a wide variety of people, including other faculty members both within and outside the BME department, as well as outside the university system (eg. industry, non-profit organizations, hospitals). One program utilizes a field trip to introduce students to a clinical environment, stimulate needs generation and familiarize them with unique challenges encountered in a healthcare delivery environment. Another program employs post-doctoral Fellows to undertake comprehensive needs gathering and vetting. The qualified needs are then used to seed the master list that students will use in the capstone design course.

One group emphasized the importance of having faculty members with experience and contacts to help identify these sources. Often it is helpful for this faculty member to have industrial design experience or at least contacts in industry or clinical settings. Some participants indicated that customers from industry or clinical departments may be willing and able to contribute financially by paying a fee for development of their designs. In general the consensus from experienced programs is that significant time may be required to develop contacts and vet potential projects. However, with successful experiences, the word gets out, and the process becomes easier. Other interesting sources for design projects include development of health care technology for third world countries, or designs for people with disabilities from the community. These sources present interesting ethical, economic, political and even communication challenges.

Finding the right type and number of faculty to involve in the design process can be key in successful design education. In some programs, all faculty members are involved in teaching design, and may find it an opportunity to engage in research or keep current with science and technology in their discipline. In others a central coordinator manages the capstone course, with varying levels of involvement from other faculty members. Multidisciplinary student teams may also warrant multidisciplinary faculty involvement in teaching design. While it is not always essential for faculty to have industry experience, use of appropriate translational terminology can be very valuable for students entering industry.

Establishment of student teams may depend on the faculty model chosen. For example a coordinator may survey the students about their interests in projects, then form the teams with attention paid to mixing and matching personalities, experience and concentration areas or “tracks”. In this manner, it may be possible to create more “interdisciplinary teams”. In addition, several participants had successful experiences with the involvement of students from majors other than biomedical engineering.

Advisor Recruitment, Selection and Retention

The group discussed the role of Advisors in the design experience. Most felt that the Advisors play a crucial role and that faculty should be engaged directly as advisors or as co-advisors with industry partners to assure that evaluation criteria are reasonably consistent among teams and that academic standards are appropriately met. There was consensus around the notion that Advisors should act as coaches to stimulate students to engage in and improve design skills, but should resist the temptation to propose solutions or act as team leaders. Advisors typically come from a pool of candidates comprised of BME faculty, faculty from other departments (eg. Mech E, Chem E, Elec E), industry volunteers, physicians, other healthcare professionals. Recruitment can be facilitated by

direct involvement by BME department heads and course coordinators as well as industry advisory committees (typically populated by members of senior management from local industry). Probably the best method of recruitment involves solicitation through supportive testimonials from previous advisors that can be transmitted via email or posted on BME department websites. Selection of Advisors should be based on criteria devised to assure a successful interaction with design teams. Advisors from industry should be asked to commit to meet with teams on regular basis (at least 2-4 times per month) and should be adept at coaching groups without dominating. Retention of Advisors from industry can be challenged by the significant time commitment often required in the capstone course. Sincere expressions of gratitude by course coordinators and students as well as ranking university officials often motivate industry advisors to return in subsequent years. If the number of advisors from industry is sufficiently large, pairs of advisors can be deployed to minimize the potentially negative effects arising from unforeseen changes in schedules due to professional conflicts that occasionally emerge. This co-advisor structure permits first-time Advisors to be mentored by more experienced Advisors, thereby increasing the pool of advisor candidates for future years.

Teaching Design: How to best incorporate instruction related to design process

Design is an integral part of the product development process. The importance of design has been recognized by organizations such as ABET that influence accreditation of BME programs. The “design experience” has been interpreted differently by BME programs throughout the country. Such differences arise from varying structure, size, age, research emphasis, faculty experiences, complexion of students, involvement of local industry representatives and duration of the design experience. Some programs expose students to design process early in biomedical engineering curriculum; others combine design process with the capstone design course to facilitate integration of process deliverables (concepts, requirements, specifications, test methods, project schedules) with design in a temporally coincident manner. For example, a lecture regarding concept generation and screening occurs just prior to assignment of homework dealing with the same topics. For BME programs that expose students to design process early in the curriculum, important elements of process may be introduced in the sophomore or junior years, thereby allowing the senior capstone course to focus on design activities and prototype fabrication.

Design in a Research Setting

The group discussed the suitability of design in research setting and concluded that if appropriately structured, design process instruction can be provided in a research paradigm. Key success factors were highlighted: 1) focus on overarching design process including identification and selection of relevant research questions, 2) prospective definition of deliverables, 3) consideration of alternative methods and approaches, 4) selection of a specific form of measurement, 5) documentation of all aspects of design elements and 6) presentation of results (oral and written forms). . While it may be more difficult in research-based design projects than in medical device prototyping, it is still

possible to identify constraints such as economic, ethical social or political issues for students to consider during the process.

Hypothesis-driven research exposes problems that need solutions. These problems can be used to create a significant design experience for biomedical engineering students. The following table compares the traditional design experience and the design experience in a research setting.

	Design in Traditional Setting	Design in Research Setting
1	Project selection	Research Question
2	Draft specs	Write hypotheses
3	Multiple design concepts proposed	Alternatives methods to answer question are considered
4	Screen alternatives and select optimal solution	Choose best experiment, method
5	Physical prototype	Preliminary data or development of instrument
6	Final report and presentation	Abstract, paper, presentation

Innovation and Intellectual Property

This group discussed and formulated the critical issues in education students about intellectual property (IP) and innovation. All agreed that students should: understand what IP is, understand how to protect it, know how to search patent databases, understand how to read a patent, and know the process of protecting intellectual property. Definitions of “innovation” and creativity were not as clear-cut. A proposed definition was that innovation is the process of understanding a problem, identifying user needs and constraints, researching the use environment and developing creative concepts for solving the problem and executing an implementation of that solution.

We discussed the process of getting the students to become innovative, and how formally design pedagogy should be taught. Several people described formal brainstorming training and practice, and we discussed the involvement of faculty or graduate students in observing or facilitating the brainstorming process. The idea of “brainwriting” as individuals during the idea germination stage can help ensure that quieter individuals have a chance to contribute. The use of simpler projects to familiarize them with the process was also proposed, for example with a “training wheels” project like an egg-drop competition or reverse engineering of an over-the-counter medical device which may be less intimidating before starting a capstone project. Rotating roles of team members can also help force involvement of each individual.

Assessments of Designs and Teams

We also discussed methods of peer assessments as well as evaluations of the overall design project. The importance of mid-stream assessments of both group dynamics and the design process were emphasized to allow a correction of problems before the final deliverable. One clever approach includes asking students to propose the distribution of an imaginary \$5K bonus among team members. For assessment of

success of the design project, checking for engineering quality as well as attention to the use of a structured design *process* was emphasized. Sources of ideas were discussed as well as the importance of identifying specific clients or end-users in clarifying design needs. Finally, an interesting discussion of the role of competitions between project teams transpired. While less competitive approaches can lead to more collaboration and sharing of resources, it may be argued that this may not provide as much real-world motivation as a contest would.

Entrepreneurship

Definition

The group adopted a working definition of entrepreneurship as: starting, organizing and operating a business. The process includes identifying a need, formulating the problem and converting an idea into something that meets the need.

Knowledge and skills

Key knowledge and skills to be developed include: ability to formulate a business plan; working knowledge of funding sources; creation and protection of intellectual property; ability to work across disciplines. The group emphasized that programs need to consider whether and how to create a culture and mindset of entrepreneurship (how to convey the sense of entrepreneurship as the willingness to take a leap-of-faith risk).

There was discussion of the fact that entrepreneurship education can occur both within and outside traditional courses. One such mechanism is a business plan competition.

Incentives

The group briefly discussed incentives for entrepreneurship among students -- including creating ownership of intellectual property and awards for "best" approaches. Caution was expressed about distracting graduate students from completing their dissertation.

Key Resources

Human resources: role models from industry or other parts of the "real world" (e.g., patent attorneys, regulatory experts) who discuss their successes and failures; departmental industrial advisory committees; former students.

Other resources: a national contest (such as the BME Innovation, Design & Entrepreneurship Award); Case studies of product/company development.