

FOUR YEAR BIOMEDICAL ENGINEERING DESIGN AT THE MILWAUKEE SCHOOL OF ENGINEERING

**John D. Gassert, Ph.D., P.E., Vincent R. Canino, Ph.D., P.E.
Milwaukee School of Engineering**

Abstract

A unique feature of the design process at MSOE is the Biomedical Engineering “senior design project” that begins in term two of the freshman year. Each student must apply to become a member of a particular team and most students will stay in that design team. During the next ten quarters, the students are expected to apply course material pertinent to their engineering project and present that application to their design advisor within two weeks of completion of each quarter. In the second quarter of the junior year, each team presents their final project specifications to the faculty, students and invited guests. In the spring quarter of the junior, each design team begins work on subsystem design specifications. These specifications are then refined into design specifications and a prototype during the senior year. This process culminates in a design show in which the products and design are judged.

Continual and progressive assessment of a student’s progress is crucial to the success of the design team. The team’s faculty advisor uses clearly defined “Engineering Design Policies and Procedures,” regularly scheduled meetings with the team, scheduled formal and informal oral reports, a formal feasibility study, and the students’ continuous use of an engineering logbook to perform this assessment. The fourth group of students is completing this design sequence in May of 1999. The resulting senior engineering design projects have been highly successful because of the continual assessment of the teams’ performance by their individual faculty advisor and the BE program faculty.

Introduction

Biomedical Engineering began at MSOE in 1972 as a Bio-Environmental Engineering Technology program. Soon after, it became a Biomedical Engineering Technology program and was accredited by the Technology Accreditation Commission of ABET. This program became a Biomedical Engineering program and was accredited by the Engineering Accreditation Commission of ABET in 1989. Over the past 26 years the MSOE BE program has gained respect as a leader in undergraduate Biomedical Engineering education and is currently one of two accredited programs in Wisconsin. The majority of students who enroll in BE at MSOE are from the Midwest. However, our national and international reputation has drawn students from all over the United States, South and Central America, Africa, the Middle East, Asia, and India.

Students interested in this program are taught that the word biomedical is a modifier to the word engineering. The BE curriculum at MSOE contains a core sequence of courses commonly found in all engineering curricula. In addition to the customary engineering science

courses, the BE curriculum includes studies in the life sciences. A graduate of the BE program will have completed 21 quarter credits of biology, organic and biochemistry, anatomy, and physiology. The life sciences are also integrated into many of the traditional engineering science courses taken by the biomedical engineering students. Continual and progressive assessment of a student's progress is crucial to improving the quality of the BE program at MSOE. The faculty at MSOE have elected to use a four year design process as the primary method of assessing the learning of the BE students.

Design in the Biomedical Engineering Program

Biomedical Engineering Design involves all the skills which differentiate an engineer from a scientist. An unique aspect of the Biomedical Engineering program at MSOE is the eleven quarter design sequence. Beginning in the winter quarter of their freshman year and continuing over the subsequent eleven quarters, the BE student is required to demonstrate that he or she possess the design skills necessary to succeed. As with the development of any skill, practice is the key to success. Engineering design can not be taught in one quarter. Learning engineering design takes practice and time. The students are expected to develop these skills and make them part of their development as a engineering professional. The objective of this engineering design experience is to prepare the MSOE BE student to practice the profession of engineering after graduation.

The Biomedical Engineering curriculum provides both the high level of education and practice required to become a Professional Engineer. The educational component of courses in engineering, mathematics, sciences, communications, humanities, social science, business and law, serves the overall needs of the student seeking to achieve professional status. The practical component is composed of the many laboratories and the more than 24 credits of engineering design contained in the curriculum. As the student moves through the curriculum, he/she is expected to apply the knowledge gained in each course to the solution of a particular biomedical engineering design problem.

Biomedical Engineering Design organization

The first course in Biomedical Engineering Design is Freshman BE Design (BE-103). The Biomedical Engineering Program Director assumes the role of Vice President of Engineering and coordinates all of the Biomedical Engineering Design activities. A faculty member is assigned to teach BE-103 and assumes the role of Chief Engineer. The Chief Engineer is responsible for project identification, the assignment of all design team personnel and, in consultation with the Vice President of Engineering, makes all policy decisions, and assign all grades. The Chief Engineer remains with the teams through the eleven quarter design process. The members of the Design Team are responsible for formulating questions and asking for guidance with design problems or procedures. The Chief Engineer does not solve problems, make specific engineering decisions, design, take charge of individual design teams, or do the work assigned to the members of the design team. Each student is required to submit a cover letter and resume requesting a position on one of the design teams. Further, each student must apply for one or more of the following positions: Group Manager, Project Manger, Associate Project Manager, or Project Engineer.

The Group Manager (GM) is an engineering member of one of the design teams for 50% of his/her time and serves as manager of all of the design teams formed in BE-103. The Group Manager is responsible to the Division Engineering Manager. The function of the Group Manager is to call meeting(s) of the Project Managers to insure that all design teams are making progress towards their design goals. Further, Group Managers are required to meet with the Vice President of Engineering and the Chief engineer every two weeks during the each academic quarter

The Project Manager (PM) is an engineering member of a design team who assumes the responsibility for organizing, coordinating and planning the activities of the design team. The Project Manager is required to attend meeting(s) called by the Group Manager.

The Associate Project Manager (APM) is an engineering member of a design team who assumes the responsibility of the Project Manager whenever the Project Manager is not able to assume these responsibilities. Further, the Associate Project Manager is responsible for scheduling meetings with the Chief Engineer, and to keep a permanent file of all design memos and reports of the design team.

The Project Engineer (engineer) is a member of a design team with specific engineering assignments. The engineer is responsible for particular design projects as agreed to by the other team members and the Project Manager. Since this is a team effort, each engineer is required to assume the duties of the Project Manager and/or Associate Project Manager if, for any reason, the Project Manager and/or Associate Project Manager can not perform those duties. Each member of the design team must work to keep the project moving toward completion on time, within specifications, and on budget.

Design Team Procedures

Design Teams are teams of engineers working in a cooperative and professional manner to achieve a common goal. Design Team Managers (Group Manager, Project Managers, Associate Project Managers) are required to accept major design assignments on their individual design teams. Any of the three management positions may be assigned to any engineer by the Chief Engineer to insure that each student gains appropriate professional experience. In most situations, grades assigned to the design team apply to all members of the design team.

Each design team engineer is required to keep an Engineering Log Book. Rules for completing such a log are given to each student in BE-103. The contents of each Engineer's Engineering Log Book is the major determining factor in judging if a student has earned a passing grade for the courses involved in the design sequence (BE-103, BE-400, BE-401, BE-402, BE-403). It is also a significant component in the assessment process.

Since the actual Engineering Log Book of an engineer is the personal property of that engineer, it is the responsibility of the APM, in consultation with the other members of the design team, to specify how each team engineer will report their work to the other members of the design team. If a design team member should resign or not be able to continue, for any reason, the other design team members need to have access to the work of that engineer. In addition, each engineer is required to submit a written summary of their work on a quarterly basis, and copies of these summaries are kept in the office of the team's Chief Engineer. Since

these Memos and Reports are not returned to the design team, the Associate Project Manager must keep copies of these items.

The Group Manager is required to call at least one meeting per quarter of the Project Managers. The meeting is to be called at a time and place agreed to by the Project Managers. The Group Manager must provide a meeting agenda and minutes of the previous meeting to each Project Manager with copies to the Chief Engineer and Vice President of Engineering.

The Project Manager must attend all meetings called by the Group Manager, lead the quarterly meeting of the design team with their Chief Engineer, and schedule at least one meeting per quarter of the members of the design team. The time and place of the design team meeting(s) must be agreed to by all members of the design team. The Project Manager must provide each member of the design team with an agenda at the time of the meeting. The team members shall be given the opportunity to make changes to the agenda with the approval of the other team members. The Project Manager is to keep the Group Manager and Chief Engineer apprised of all problems and/or recommendations of the design team.

The Associate Project Manager is responsible for scheduling quarterly meetings with the Chief Engineer and keeps copies of all design memos, agendas, minutes, and reports of the design team. There are two policies under which all design teams are to operate. First, all design team engineering decisions are to be made in a cooperative and professional manner with all members taking an active part in the decision making process. Second, each member of a design team may, at any time, discuss problems with the Group Manager, Chief Engineer, or Vice President of Engineering.

The students must make every effort to complete at least 10 hours of work on the design project during every subsequent quarter and during the summer breaks. They are required to write a design memo on the work completed and give the memo to the APM. This will continue until the winter quarter of the junior year when each design team must give the Formal Junior Biomedical Engineering Design Presentation.

The GM is responsible for organizing and conducting the Oral Presentations of the Junior Design Report during the second week of the quarter. The PM is responsible for organizing the design team's Oral Presentation of the Biomedical Engineering Junior Design Report and must schedule at least one design meeting and plan final design specifications. The final design specifications must be presented in the form of a written memo to the Chief Engineer, with a copy to the VP of Engineering. The final design specifications must receive written approval from the Chief Engineer and VP of Engineering.

The APM is responsible for organizing of the Formal Junior Design Report and giving copies to the Chief Engineer and VP of Engineering prior to the Oral Presentations. The APM must also schedule a meeting of the design team with the Chief Engineer.

The engineers are required to work on final preparations for the Oral Design Presentation, complete the Formal Junior Report, attend all design team meetings, and prepare the final design specifications.

The Chief Engineer assigns a team grade for the Oral Presentation and a team grade for the Formal Junior Design Report. After grades have been assigned for the Oral Presentation and Report, the Chief Engineer calculates a Design Team Grade. This grade is composed of all grades assigned to the design team. Each team must earn at least a 70. If the Design Team Grade is not at least a 70, team members is not allowed to register for BE-400. Further, each member of the design team must also meet all prerequisites for BE-400. Any engineer not meeting the prerequisite requirement is required to resign from the team and apply to a sophomore year design team.

Beginning in quarter nine and ending in quarter twelve, the design teams work on subsystem design, prepare design memos covering the work completed in each quarter, attend design team meetings, and attend design team meeting(s) with the Chief Engineer, as directed by the Chief Engineer. Design team performance is graded by the Vice President of Engineering, and that grade is factored into the final grade assigned for BE-400 by the Chief Engineer. During the summer between the junior and senior year each member of the design team is expected to spend at least 20 hours working on assigned design team activities.

In BE401, which is taken during quarter ten, the PM is responsible for making sure that design specifications, ethical, moral, legal, and economic issues are resolved by the members of the team. An Oral Presentation and Formal Report is used as the Final Examination in this class. The APM is responsible for collecting from each engineer drafts of various sections of the Final Formal Design Report. Copies of the rough drafts are to be sent to the Chief Engineer. The engineers work on individual designs, submit rough drafts of sections of the Final Design Report, and prepare written and oral presentations required in BE-401. If possible the Vice President of Engineering and all of the Biomedical Engineering faculty attend the Formal Oral Presentation. The Chief Engineer may also invite other interested parties. The presentation is not open to the public.

BE402 is taken during quarter eleven and the PM must plan and organize design activities of team in and outside of BE-402, plan all meetings with the Chief Engineer, attend PM meetings, and organize and coordinate the team's Engineering Design Review. The APM must schedule meeting(s) with the Chief Engineer, provide the GM with the information needed for the Biomedical Engineering Design booklet, collect and copy drafts of completed sections of the Final Biomedical Engineering Design Report, and collect, copy and distribute written reports to be used in the Engineering Design Review. The engineers must attend design team meeting(s), participate in the writing of the materials needed for the Design Show, write and submit to the APM drafts of your sections of the Final Design Report, and write and submit to the APM materials to be used in the Engineering Design Review.

The lecture material for BE-402 is team taught by members of the BE faculty and final grades is assigned by the Engineering Design Review Committee. The final examination in BE-402 is a complete review of each team's proposed design. The Engineering Design Review is scheduled as soon as the team is ready; it does not have to be during final examination week. The Engineering Design Review Committee is composed of the Vice President of Engineering, the Chief Engineer and at least two other Biomedical Engineering Faculty. The Chief Engineer may also invite other interested parties. The Engineering Design Review is an informal meeting closed to the public and the other design teams.

Quarter 12 is when BE403 is scheduled and during this course the GM must plan and organize the Biomedical Engineering Design Show under the direction of the Chief Engineer and Vice President of Engineering. The PM must organize and lead at least two meetings with the Chief Engineer, coordinate the work of the design team, coordinate the writing of the Final Formal Design Report, and organize and coordinate the team's Biomedical Engineering Design Show Presentation. The APM collects and copies the Final Design Report, give copies of the report to the Chief Engineer and Vice President of Engineering prior to the BE Design Show, and schedule at least two design team meetings with the Chief Engineer. The Engineers attend design team meetings, complete all design sections, write final sections of the Final Design Report, and participate in the BE Design Show. Final team grades are assigned by the Vice President of Engineering and the Chief Engineer.

Conclusion

A unique feature of the design process at MSOE is that all Biomedical engineering students begin their "senior design project" in term two of their freshman year. During the eleven quarters of design, the students are expected to apply course material germane to their engineering project. Each team must finalize the customer specifications and present their project specifications to the faculty, students and invited guests in the junior year. These specifications are then refined into design specifications and a prototype during the senior year. This process culminates in a design show in which the products and design are judged. The fourth group of senior BE students completed this four year design sequence in May of 1999.

Continual and progressive assessment of a student's progress has been crucial to the success of the Biomedical Engineering design process. The team's faculty advisor have used clearly defined "Engineering Design Policies and Procedures," regularly scheduled meetings with the team, scheduled formal and informal oral reports, a formal presentation on the produce specifications, and the students' continuous use of an engineering logbook to perform this assessment. The resulting senior engineering design projects have been highly successful because of the continual assessment of the teams' performance by their individual faculty advisor and the review of the BE faculty.

Vincent R. Canino

Vincent Canino is currently a Professor in the Electrical Engineering and Computer Science Department at Milwaukee School of Engineering. His positions at MSOE include Professor of Electrical Engineering and Computer Science, Director, Biomedical Research Institute, Program Director of Biomedical Engineering, and

Program Director of Master of Science in Perfusion. Canino received his Ph.D in Electrical Engineering (Biomedical Option), August 1976 from Marquette University. He was responsible for developing the Biomedical Engineering Program and the Perfusion program at MSOE and has also developed and taught courses at both the graduate and undergraduate level in Biomedical Engineering, Perfusion, Electrical Engineering, Computer Engineering, and Electrical Engineering Technology.

John D. Gassert, Ph.D., P.E.

John Gassert is currently a Professor and Vice Chairman of the Electrical Engineering and Compute Science Department at Milwaukee School of Engineering. He received his Ph.D. Biomedical Engineering in 1995 from Marquette University. Gassert has developed and taught courses at both the graduate and undergraduate level in Biomedical Engineering, Medical Informatics, Perfusion, Electrical Engineering, Computer Engineering, and Electrical Engineering Technology. Prior to arriving at MSOE, Gassert spent seventeen years in industry in positions as a design engineer, a clinical engineer and a consultant.

