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Work in Progress: Providing Diverse Opportunities for Capstone Projects in Biomedical Engineering

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Dr. Meyer directs the Experimental Biomechanics Laboratory (EBL) at LTU with the goal to advance experimental biomechanics understanding. Dr. Meyer teaches Introduction to Biomechanics, Tissue Mechanics, Engineering Applications in Orthopedics and Foundations of Medical Imaging. He has been an active member of the engineering faculty committee that has redesigned the Foundations of Engineering Design Projects course that is required for all freshman in the College of Engineering at LTU. This committee is currently designing a new sophomore-level Engineering Entrepreneurship Studio that will also be required for all students as a continuation of the ”Foundations studio”. He has published 33 peer-reviewed journal and conference proceeding articles. At LTU, Meyer offers a number of outreach programs for high school students and advises many projects for undergraduate students.

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Yawen Li is an associate professor in the biomedical engineering program at Lawrence Technological University. Her teaching portfolio include courses such as Biomaterials, Tissue Engineering, Tissue Engineering Lab, MEMS, MEMS Lab, and Engineering Materials. Serving as the university assessment committee representative since 2011, she coordinates various aspects of the assessment-related activities within the program.

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Abstract

A survey of 19 Biomedical Engineering (BME) senior projects, over a period of five years at Lawrence Technological University, shows a range of projects from applied research to design based. To provide uniformity in course instruction and assessment of these different types of projects, the *process* of taking an idea from inception to implementation is emphasized. All student teams follow a similar process of opportunity recognition, customer interaction, market analysis and design proposal. Direct and indirect assessments are used for a variety of individual and team based assignments and provide the statistical data for analysis of student performance and progress. Teams are required to remain in contact with project advisors who provide guidance in the discovery phase and help with resource gathering during the implementation of proposed ideas. The distributed course model, described in this paper, can be implemented in any project-based course to provide the necessary flexibility in dealing with different types of projects while adhering to a uniform method of course instruction and assessment.

Capstone Senior Projects in Biomedical Engineering

The importance and methodology for offering design[1] or research-based[2] approaches to capstone senior projects have been discussed previously in the literature. By providing the students with an array of options to look for unmet biomedical needs and then relying heavily on mentorship and guidance from project advisors during the ideation phase, we have had success in developing a flexible yet unified process to simultaneously run applied research and design projects within the same capstone series. Results have been encouraging with many projects resulting in intellectual property and/or scientific publications, while meeting the learning outcomes for the course. There are two points relative to this discussion that are worth mentioning:

I. Qualitative assessment of the senior projects led to the realization that seniors were not properly prepared to seek their own project ideas, which is a critical component of the whole process. This prompted us to revisit the overall BME curriculum and several changes were instituted in the freshman, sophomore and junior level courses that lead up to the senior design.

II. In our experience, pure research projects, although possible, work better as (individual) directed research since only a few students are inclined to spend the time needed to conduct an in-depth literature review of the topic area of interest. Students also find it more difficult to define team responsibilities and self-assign tasks in a curiosity and

knowledge driven research project. Therefore, applied research is more beneficial at the undergraduate level.

Ideation Process in Senior Project

Figure 1 shows all the resources that are used by the students to work on four major milestones during the semester. The first two enable the students to gather necessary information to find ideas to work on as well as find peers who are willing to collaborate in a team. The last two target the development of concepts and then choosing one that is most appropriate. Students are encouraged to develop design and research ideas which may stem from the need to:

a. Improve existing technology and methods
b. Find new methods and processes
c. Repurpose existing non-medical technology for a biomedical applications
d. Modify a biomedical technology for use in environments with fewer resources
e. Modify a biomedical technology for use by a different customer base

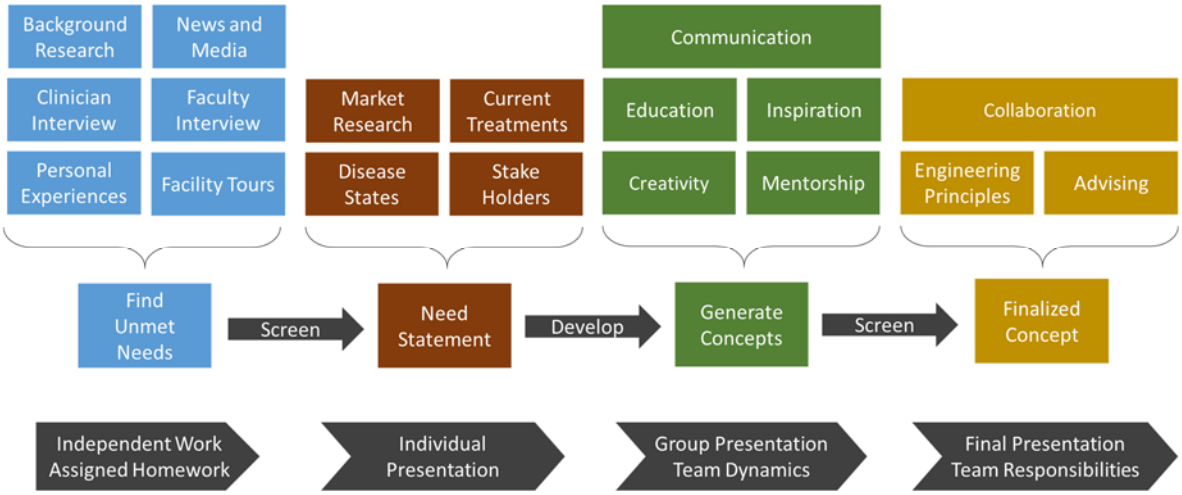

Figure 1: The general layout of the senior project course with the type of assessment tools used.

The rationale behind repeatedly requiring the students to find/create many options and then choosing one/few, is to give them practice in developing and using a selection criterion based on real-world constraints like feasibility, availability of resources and time constraints. Team dynamics, collaboration and effective communication are also essential for best outcomes.

The students are required to communicate with the developers and users of biomedical technologies and use this interaction to assist them in forming ideas for all projects. Client meeting are a critical part of the process and are most effective in generating ideas for projects. Depending on students' interests and professional goals, they may choose to meet and interview researchers (academic and industrial), clinicians, nurses and even patients. In order to help students in this process, we organize seminars by Lawrence Tech faculty, collaborators and clinicians. Students are given the opportunity to visit local hospitals, clinics and senior care

centers for direct observation of medical facilities. Through a collaboration with School of Nursing and Mechanical Engineering at University of Detroit, Mercy and a local VA hospital, BME students also interact with patients/clients with physical disabilities.

In general, the students who are interested in research or are considering graduate schools, gravitate towards faculty in BME, other engineering and science departments to find research projects. To prevent the students from simply asking the faculty for ideas for research projects, we advise the faculty to only direct students towards general topics and relevant scientific literature. The ideas for specific research projects must still stem from an unmet need that is recognized by the students and is within the research interests of the appropriate faculty member.

Students identify their interests and then create a questionnaire for an interview with the appropriate person, with the goal of finding unmet biomedical needs. The questionnaire and the responses are assigned as homework that is individually submitted by all students. Students meet with the instructor and discuss the progress towards generation of ideas based on the interview.

Grade Distribution for Different Activities

Table 1 shows the grade distribution for various activities in the course syllabus during the semester. Initial group presentations and written assignments are worth 10% each. This is designed to give the students enough time to recognize their individual responsibilities and develop good team dynamics. Individual presentations allow students to learn about different ideas and spur student interaction and conversation that is necessary for team formation. Meetings with advisors and periodic assessment of personal and group notebooks is an excellent indicator of individual and group progress. It also emphasizes good record keeping habits.

Table 1: Course assignment, timeline and grade distribution for the first semester capstone project

Assignments	Percentages	Time Frame
Attendance and in-class participation	5%	Whole Semester
Personal logbook	5%	Weeks 3, 7, 11, 14
Group lab notebook	5%	Weeks 6, 11, 15
Homework	5%	Mostly Weeks: 1-5
Individual Need Statements Presentation	10%	~ Week 4-5
Written Need Statement Report	10%	~ Week 6-7
Group Concept Presentation	10%	~ Week 9-10
Final Proposed Design Presentation	30%	~ Week 15
Final Written Report	20%	~ Finals Week

Assessment Data

Student self-assessment shows that assignments and interactive classroom activities help them to learn about ideas for many projects and they utilize this interaction to develop teams.

Table 2: Student's self-assessment of their ability to conduct self-directed learning while considering various constraints on a scale of 1-4 with 4 as being most capable

	Capability Scale			
Learning Objectives	4	3	2	1
Construct a system or process to meet desired needs within such realistic constraints as economic, environmental, social, political, ethical, health and safety, feasibility and sustainability.	52%	48%		
Demonstrate the ability for self-directed learning by planning, research and design for the project.	78%	22%		

Student comments generally indicate that the course structure helped with finding out new ideas

"Good design of the class. Helps to generate ideas initially. Concept of idea generation explained really well."

The exit interviews respondents have also "*made numerous positive references to the senior capstone sequence*" citing that it is one of the most constructive aspects of BME degree.

Table 3: On a scale of 1-5 (with 5 as Strongly Agree), the student evaluation of the overall course effectiveness for the last three years.

	2012-2013	2013-2014	2014-2015
Overall, the course was effective.	3.67 ± 0.9	4.09 ± 0.7	4.83 ± 0.4

Conclusion

A critical part of the senior project is for the BME students to be able to interact with users of medical technology, conduct market analysis and literature search, with the aim of finding the current state-of-the-art and the gaps in the technology. Based on this information students have the option to choose a design or research based project. Thus, the course instructor is not only responsible for teaching about the process of ideation but must also act as the facilitator for coordinating various opportunities and resources for real-world interactions. The course assessment indicates that student feel confident about their ability to generate ideas and course effectiveness has improved as the avenues for students to pursue senior projects have increased in number.

References

[1] Gassert, J.D.; Enderle, J.D., "Design versus research in BME accreditation [ABET requirements and why research cannot substitute for design]," Engineering in Medicine and Biology Magazine, IEEE , vol.27, no.2, pp.80,85, March-April 2008. doi: 10.1

[2] Healey, Mick, and Alan Jenkins. Developing undergraduate research and inquiry. York: Higher Education Academy, 2009.