Enhancing biomechanical engineering education through problem based learning

Alisa Morss Clyne, PhD, Associate Professor
Mechanical Engineering and Mechanics
Drexel University

Abstract

Mechanical engineers often have limited understanding of current biomechanical engineering research areas and how they apply to biomedical technology. Through a National Science Foundation Transforming Undergraduate Education in STEM grant, we redesigned MEM 304: Introduction to Biomechanical Systems into a problem-based learning course focused on current biomechanical research challenges. Course modules included medical device design, cellular and tissue biomechanics, biomanufacturing, bio-microfluidics, and bio-inspired robotics. Each module was inspired by a real-world task, and students completed hands-on laboratory projects as part of each module's learning progression. Through this course, student co-operative education experiences, and biomechanical engineering senior design projects, we will improve education of biomechanical engineers who can translate laboratory discoveries into cutting-edge biomedical technology.

Introduction

The Problem

- Lag between bioengineering bench discovery and clinical implementation.
- Current Drexel biomechanical engineering courses do not focus on translating faculty research into consumer devices.
- Real-world engineering knowledge from co-op is not effectively connected to classroom learning.
- Drexel students do not experience research due to the cooperative education schedule.

The Opportunity

- Drexel is a leader in engineering education innovation, with a strong focus on hand-on experiences throughout the curriculum.
- Mechanical engineering faculty are leaders in applied biomechanics research.
- Problem-based learning enhances students' ability to apply knowledge.

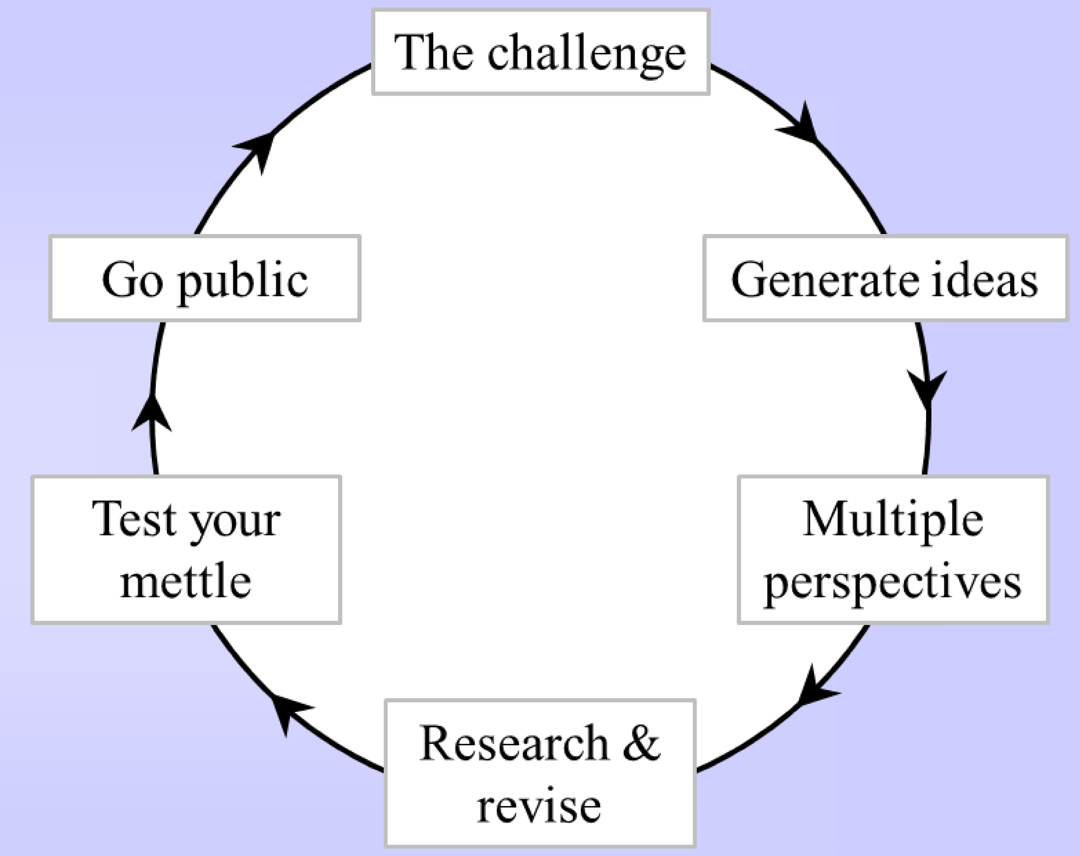
Program Goal and Hypothesis

- **Goal**: create a curriculum to educate biomechanical engineers who will translate fundamental research into new technology.
- **Hypothesis:** problem-based learning that leverages industry, research, and community partners can be successfully integrated with cooperative education and senior design to produce engineers who bridge the gap between research and development.

Methods

1. Modify existing junior level courses into a problem-based biomechanical engineering curriculum
   A. MEM 304: Introduction to Biomechanical Engineering (Fall)
   B. MEM 435-Bio: Bio Product Design and Engineering (Winter)
2. Integrate cooperative education by involving co-op employers in course and design project development, as well as incorporating student co-op experiences into the classroom.
3. Leverage biomechanical engineering faculty expertise in problem-based learning to integrate innovative classroom techniques across mechanical engineering curriculum.

	Fall	Winter	Spring	Summer
Junior	Intro Biomechanical Engineering	Bio Product Design & Engineering	Bio Co-op	
Senior	Senior Design Project in Biomechanical Engineering			



The VaNTH STAR Legacy Cycle

Results

Problem Based Learning Module: Cystic Fibrosis

Module 2: Lung Biomechanics

Problem Introduction and Learning Issue Discussion/Quiz

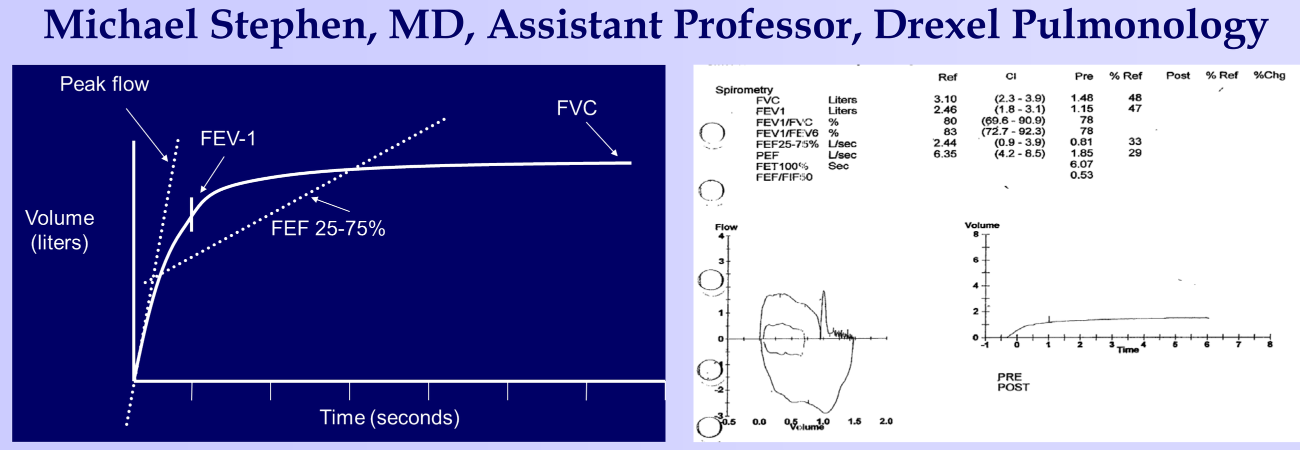
10 year old Sarah M. suffers from cystic fibrosis and recently was given 1-3 months to live. Sarah was too young for an adult lung transplant, but no pediatric lungs were available. Her parents petitioned Health and Human Services Secretary Kathleen Sibelius to intervene, but she refused. However, a federal court judge granted a temporary order that allowed Sarah to join the adult organ transplant list, and she subsequently received a double lung transplant.

Kathleen Sibelius appoints you as the lead engineer to determine how to measure lung function decline in patients with cystic fibrosis before and after lung transplantation.

Questions to ask:
1. What do you know about lung function in health and cystic fibrosis?
2. What do you need to know about lung tissue and fluid biomechanics ?

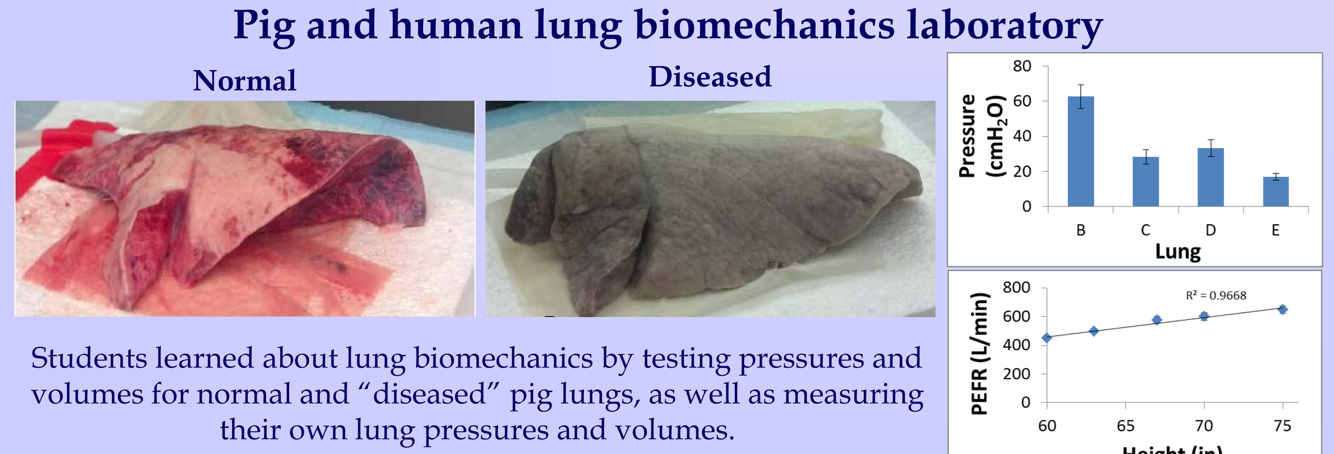
Learning issues:
1. Which fluid mechanics principles do you need to use to analyze lung function?
2. Which solid mechanics principles do you need to use to analyze lung function?
3. What lung anatomy and physiology concepts do you need to know?
4. What are the mechanisms by which cystic fibrosis damages the lungs?
5. How are cystic fibrosis patients monitored and treated?

Mini-lecture on cystic fibrosis and pulmonary function test analysis
Michael Stephen, MD, Assistant Professor, Drexel Pulmonology



Students learned about normal and diseased PFTs by interpreting real patient tests.

Pig and human lung biomechanics laboratory



Students learned about lung biomechanics by testing pressures and volumes for normal and "diseased" pig lungs, as well as measuring their own lung pressures and volumes.

Final Deliverable: 1 page executive summary recommending a PFT for patients with cystic fibrosis with lab data as supportive appendix

Module 3: Lung Biomanufacturing

Problem Introduction and Learning Issue Discussion/Quiz

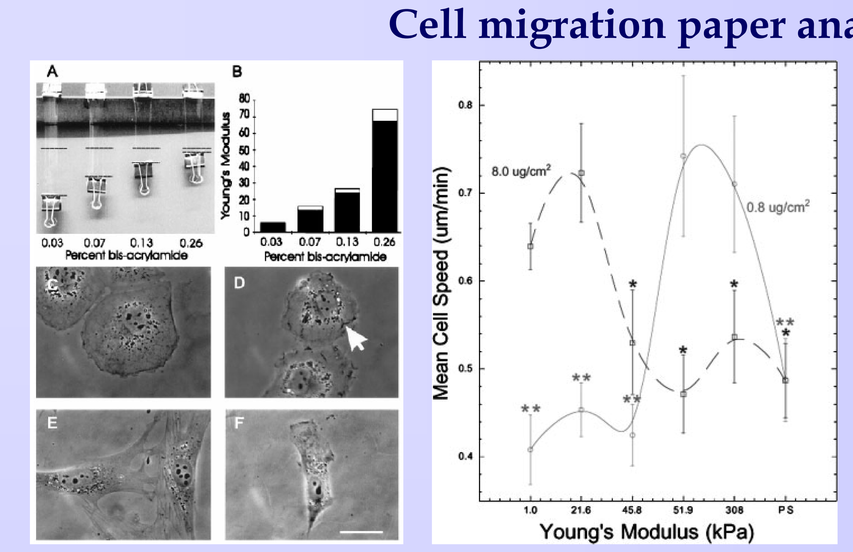
10 year old Sarah M. received a set of adult lungs; however she rejected her first lung transplant (acute rejection. In fact, most transplanted lungs are rejected. Despite the low donor lung supply, Sarah received a second set of lungs and contracted pneumonia. Patients who receive lung transplants are placed on immunosuppressive therapy to prevent rejection, which then increases their risk of developing lung infections that damage the transplanted lungs.

You decide to start your own company to develop tissue engineered lungs to increase the lung supply for transplant as well as remove the (acute) rejection problem.

Questions to ask:
1. What do you need to know about lung components?
2. What are the important biomanufacturing processes in tissue engineering?

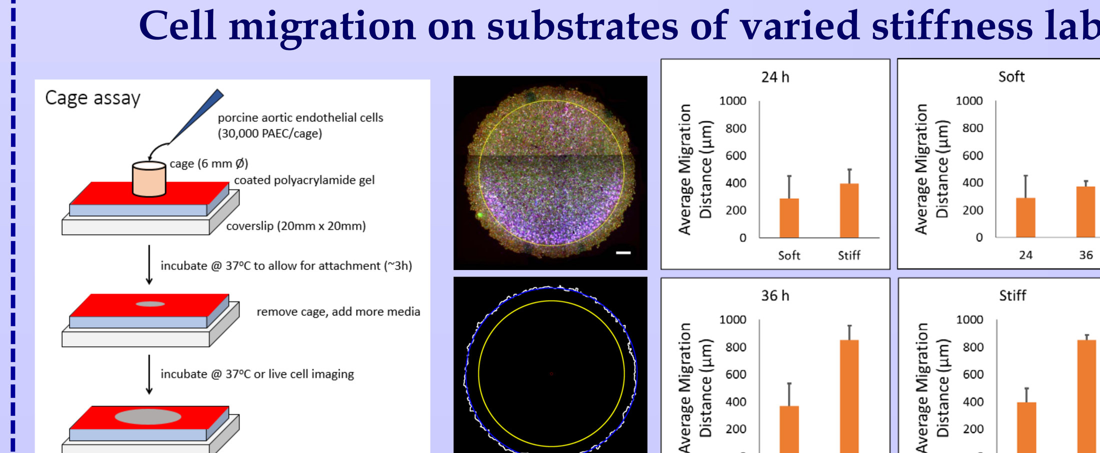
Learning issues
1. What scaffold materials are used in tissue engineering?
2. What manufacturing methods can be used to create the scaffold?
3. What cell types are present in a lung – in bronchi, alveoli, and blood vessels?
4. What mechanical stimulation would the developing lung need?
5. What key properties of lungs need to be replicated in the tissue engineered lung?

Cell migration paper analysis



Students learned about the effect of substrate stiffness on cell migration by interpreting data from published papers in the field. (Left) Pelham and Wang, 1997. (Right) Peyton-Putnam 2005.

Cell migration on substrates of varied stiffness laboratory



Students tested the effect of substrate stiffness on cell migration using current laboratory techniques.

Final Deliverable: Lung biomanufacturing system design with lab data as supportive appendix

Conclusions

- Engineering students enjoyed the hands-on nature of the course
- Initial student deliverables often did not meet quality and depth expectations; however, deliverables improved dramatically with faculty critique followed by student revision
- Medical doctors enjoyed interacting with engineering students
- 1/3 of students who went on co-op in the spring-summer cycle took a biomechanical engineering position
- Faculty did not feel that the problem based learning format significantly increased their workload, after problem formulation.

Future Work

- Analyze student journals to understand their perceptions of changed knowledge in biomechanical engineering
- Interview program faculty to assess effect on their teaching style
- Survey students on how the course applied to their co-op experiences.
- Analyze employer co-op surveys to interpret the quality and usefulness of curriculum for co-op.
- Encourage students to develop MEM435 or Senior Design projects based on their co-op experiences.
- Collaborate with engineering leadership to provide workshops and incentives for faculty to implement problem based learning in the engineering curriculum.

Acknowledgements

This project was funded by NSF TUES DUE-1141186. I thank my collaborators, Dr. Moses Noh and James Tangorra, as well as the graduate student teaching assistants who made the entire course possible.

Drexel University College of Engineering
Mechanical Engineering and Mechanics

Drexel University Center for Academic Excellence