Merging Education, Research and Industry: Teaching Biomedical Engineering Design for Social Impact

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Project-based Learning and Human Centered Design in the Classroom

• Recently, engineering programs have shifted towards encouraging students to develop deeper levels of contextual understanding\(^1\)
  - Challenge students to critically reflect on the broader impacts of their work
  - Develop real-world skills such as persistence, flexibility, and adaptiveness that are necessary for professional success

• An example to promote this in the classroom is through project-based learning (PBL)\(^2\) and human-centered design (HCD) thinking\(^3\) which provide a toolkit for needs assessment, creative ideation, and rapid iterative improvement for solving problems.

• Recommendation that engineering programs make design pedagogy a high priority in future resource allocation decisions\(^4\).

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Project-based Learning and Human Centered Design in the Classroom

• An application of PBL and HCD thinking in the classroom has been in the cross-disciplinary field of development engineering, which aims to design appropriate technologies to spur economic and social development in areas with limited resources.5

• HCD thinking as applied to development engineering is unique in its focus on6:
  1. incorporating international development goals
  2. scaling for impact
  3. Integrating novel yet lean technologies

• A pioneer in this field is the MIT D-Lab

D-Lab

Development through discovery, design, and dissemination

Development of appropriate technologies and sustainable solutions within the framework of international development
D-Lab Programs

D-Lab Scale-Ups Fellowships
d-lab.mit.edu/scale-ups/all-fellows

MIT Scaling Development Ventures Conference
sdv.mit.edu

International Development Innovation Network
idin.org

Comprehensive Initiative on Technology Evaluation
cite.mit.edu

D-Lab Youth Outreach
d-lab.mit.edu/youth-outreach
D-Lab Workshop/Makerspace

Love to build things by hand? Welcome to the D-Lab shop!

Never hammered a nail before? Welcome to the D-Lab shop!

- A workshop for international development makers
- Open to all students in D-Lab courses
- Hand tools, power tools, welding, metal fabrication, wood shop

d-lab.mit.edu
D-Lab Undergraduate Research Opportunities (UROP)

- Biomass Fuel & Cookstoves
- Mobile Technology Lab
- Off-grid Energy Solutions, Assessment & Implementation
- D-lab Scale-ups
- Local Innovation & Development
- And many others!

d-lab.mit.edu
D-Lab Courses at MIT

A few examples from Spring 2017:

• Humanitarian Innovation
• D-Lab: Water and Climate Change
• D-Lab: New Economies
• D-Lab: Earth
• D-Lab: Design
• D-Lab: Energy
• **D-Lab: Prosthetics for the Developing World**
• Design for Complex Environmental Problems

d-lab.mit.edu/courses
Why ‘Prosthetics for the Developing World’?

Only 5-15% of amputees in low- and middle-income countries receive a prosthetic device.

A closer look at prosthetics in India...

INTRODUCTION: D-LAB PROSTHETICS

Extreme affordability

Costly

Lack of options
Course Overview

- **Overall goal**: completely immersive design experience
  
  - **Clinical challenge** defined by a partner organization related to prosthetic, orthotic, or rehabilitative technology
  
  - Work as part of a team to **Design**, **Prototype** and **Evaluate** a solution
Course Goals

1. Gain understanding of **technical challenges** faced in developing nations
2. Learn about **appropriate prosthetic technologies**
3. Explore how MIT can be involved with **developing world challenges**
4. Learn **hands-on skills**, like CAD and prototyping
5. Understand challenges of **innovation and entrepreneurship** in resource-constrained settings
6. Learn about **design for scale**
COURSE STRUCTURE: DESIGN PROCESS

- Problem Definition
- Background Research
- Mission Statement
- Functional Requirements & Design Parameters
- Strategy to Concept
- Design
- Experimental Evaluation/Validation
Problem Definition

- International partners provide challenges that they face.
Background Research

- Emphasize understanding the **challenge** that the student team is working on

- Suggestions for getting started:
  - Literature search
  - Patents
  - Prior Art
  - Web Search
  - Interviews/shadowing
**Mission Statement**

- A clear and concise statement about what the team plans to accomplish during the semester.

**Clear and concise** statement about what the team plans to achieve during the semester

Focuses the team and is a good way to start presentations

**Important considerations:**
- What problem is the team trying to solve?
- What does the design need to do?
- Who are you innovating for?
- What value are you adding?
Functional Requirements
A list of independent functions that the design must accomplish [What?]

Design Parameters
Independent means to accomplish each functional requirement [How?]

<table>
<thead>
<tr>
<th>Functional Requirements</th>
<th>Tech Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be able to adjust height</td>
<td>1-7 +/- 1 mm</td>
</tr>
<tr>
<td>Accommodate variable cane diameters</td>
<td>25-35 mm</td>
</tr>
<tr>
<td>Accommodate difference in diameters of two canes</td>
<td>+/- 5 mm of each other</td>
</tr>
<tr>
<td>Accommodate gap between canes</td>
<td>1 cm</td>
</tr>
<tr>
<td>Cost effective</td>
<td>&lt; ₹1000 (~$15)</td>
</tr>
<tr>
<td>Lightweight</td>
<td>&lt; 200g</td>
</tr>
<tr>
<td>Strong</td>
<td>Test with ISO 10328 guidelines</td>
</tr>
<tr>
<td>Made from accessible materials</td>
<td>Aluminum, PP, PE</td>
</tr>
<tr>
<td>Waterproof</td>
<td>Yes</td>
</tr>
<tr>
<td>Withstand range of temperatures</td>
<td>30-110° F</td>
</tr>
<tr>
<td>Attach to standard parts</td>
<td>Pyramid adaptor, receiver, pylon</td>
</tr>
</tbody>
</table>

• “Coarse to fine”

• **Strategy**: *broad* way to approach the problem

• **Concept**: *specific* devices that will meet your design goals

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- A means to realize chosen concept

- Break up design into modules
  - Determine most critical module; prototype this first

- Design for resource-constrained environments
  - Know your constraints
  - Seize opportunities to be creative

**Source:** EC.722 Design Project – R. Das, M. Devlin, L. Zimmermann, J. Gamble, J. Kudryashev
Experimental Evaluation/Validation

- Bench-top experiments and/or field testing to determine if the functional requirements have been met.

Source: EC.722 Design Project – A. Flaherty, S. Le, M. Marzoughi, C. Nobuhara, A. Rajagopal
COURSE STATISTICS

Course Enrollment
(n=97 students; 2008-2017)

Student Gender Distribution
(n=97 students; 2008-2017)
COURSE STATISTICS

**Student Year Distribution**
(n=97 students; 2008-2017)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>15</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
</tr>
<tr>
<td>2010</td>
<td>7</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
</tr>
<tr>
<td>2014</td>
<td>10</td>
</tr>
<tr>
<td>2015</td>
<td>20</td>
</tr>
<tr>
<td>2017</td>
<td>25</td>
</tr>
</tbody>
</table>

**Student Year Distribution [Total]**
(n=97 students; 2008-2017)

- Year 1: 26%
- Year 2: 26%
- Year 3: 33%
- Year 4: 14%
- Grad: 1%

D-Lab
Student Major Distribution [Total]
(n=97 students; 2008-2017)

- Mechanical Engineering: 65%
- Bio/biomedical Engineering: 12%
- Other Engineering (Electrical, Chemical, Materials): 12%
- Science (Biology, Physics, Chemistry, Neuroscience): 7%
- Business or Social Science: 4%
Speakers from experts in the field:
PARTNERSHIPS

Industry collaboration and sponsorship:

Source: Autodesk Design Academy
[academy.autodesk.com]
PARTNERSHIPS

MIT International Science & Technology Initiatives

JOIN THE WORLD THROUGH MIT-INDIA
DISCOVER INTERNSHIP & RESEARCH OPPORTUNITIES

Source: misti.mit.edu
Project Continuation

• Since 2014, there have been 13 student projects – 8 projects have continued beyond the class
Project Continuation

- Since 2014, there have been 13 student projects – 8 projects have continued beyond the class
  - Field-testing
  - Additional grant money
  - Industry internships
  - Patents
  - Start-up venture

Photo credit: M. Cavuto & M. Chun
Transfemoral Rotator (India)

Key accomplishments:
- Multiple field trials at Jaipur Foot and Mobility India
- 2nd place prize in the 2016 MIT de Florez Competition
- Manuscript in ASME
- Filed a utility patent
- DFM project in current course

Student team: K. Baronov, M. Chun, M. Cavuto, K. Durgin, N. Kelsall, M. Zhou

SmartSocket (Kenya & Ethiopia)

**Key accomplishments:**
- Field testing with CURE International
- Secured funding from the MIT Undergraduate Giving Campaign (UGC) and Tau Beta Pi
- MIT IDEAS Global Challenge Winner

**Student team:** K. Sweeney, E. Green, T. Luu, N. Schwarz, K. Swaminathan
Adjustable Socket (Rwanda)

Student team: C. Humure

OUTCOMES: CASE STUDIES

Key accomplishments:
- Preliminary field testing at Mobility India
- Continued project as intern at Autodesk
- Created course on Autodesk Design Academy
- Ozy Genius Award Winner
Conclusion

- Work with international collaborators to define real-world challenges
- Partnerships with industry
- Team project-based learning – design and making as a way of learning
- Human-centered design thinking that is societally, financially, and technologically sensible for intended setting
- 8 of 13 projects continued beyond the course
- Exposure to biomedical design for social impact
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Matthew Chun
Shriya Srinivasan

On-campus collaborators
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MISTI-Arab World (David Dolev)
MIT Undergraduate Giving Campaign
MIT Tata Center
MIT IDEAS
MIT Media Lab
Biomechatronics Group (PI: Hugh Herr)
GEAR Lab (PI: Amos Winter)

International collaborators (past & present)
Jaipur Foot Organization [India]
Refugee Open Ware [Jordan]
Mobility India [India]
CURE International [Kenya & Ethiopia]
STAND: The Haiti Project [Haiti]
Transitions [Guatemala]
RiseLegs [India]
Gateway Prosthetics [Kenya]

MIT D-Lab
Libby Hsu
Nancy Adams
Bob Nanes
Jack Whipple
Richard Brewer
Amy Smith
Melissa Mangino
Victor Grau Serrat

Local collaborators (past & present)
Rogerson Prosthetics and Orthotics
A Step Ahead Prosthetics
Continuum Innovation
IDEO
MGH CAMTech

Autodesk
Sunand Bhattacharya
Erica Nwankwo
Mike Alcazaren
Natalia Polikarpova
Thank you! Questions?

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