Introduction to Soft Robotics

Developed by: Soft Robotic Toolkit team @ Harvard Biodesign Lab

About this course:
Imagine robots that look like caterpillars and starfish! Although the world of robotics is currently dominated by rigid, metal body robots, the “Next Big Thing '' in robotics is - Soft Robotics! Soft robots are highly flexible and lightweight systems. Their soft, deformable materials can accomplish tasks that would be unimaginable by traditional, rigid robots.

Around the world, designers and engineers are using soft robotics to create applications for a range of industries. For instance they are creating slithery mechanisms that can be used in space and underwater explorations, soft and precise gripping mechanics for agriculture, food packing and e-commerce industries, assistive devices and responsive apparel to enhance people’s everyday life, medical and surgical devices, etc.

This hands-on, introductory course is divided into two phases. In phase one students learn the basics engineering and robotics as they build a soft robotic gripper. Students are exposed to manufacturing with soft materials, biodesign, using cables and motors to create movement and incorporating sensors and microcontrollers to automate the gripper. In phase two students learn about and apply the engineering design process to solve a design challenge.

Learning Outcomes:

After completing Phase 1 students will be able to:

- **Describe** the basic elements of a robot
- **Understand** bio-inspiration in design
- **Analyze** how soft robots are different from rigid robots

Make an acrylic mold and cast silicone
Build a robotic actuation system using Motor, Cable and Pulley
Assemble a circuit using a printed circuit board
Set up Sensing and Control system for the robot using an ultrasonic range sensor and an Arduino

After completing Phase 2 students will be able to:

- **Design and Construct** a soft actuator to solve a problem
- **Understand** the engineering design process
- **Cultivate** maker mindsets like risk-taking and troubleshooting

Brainstorm designs for new actuators for the gripper
Sketch multiple actuator designs
Rapidly prototype new designs
Test successes and limits of new actuators and iterate
Make an impression mold using play doh
Create and cast bioplastic to build new actuators

Course Design:

Active learning
We believe that students learn best when they are actively engaging with the course content, the instructor and their peers to construct meaning. Hence, all lessons for the starter curriculum follow the 5E model of instruction creating opportunities for students to actively engage in meaning making.

Blended Model
The course is designed to be facilitated in a blended format with some work happening synchronously and the remaining work happening asynchronously. The curriculum suggests what parts can be conducted asynchronously and which parts would benefit from synchronous facilitation. At the beginning students spend a larger proportion of time in synchronous lessons learning about the new concepts but as the course progresses and students start working on their independent projects, more time is spent asynchronously, in small groups or in 1-1 coaching and less time is spent in synchronous lessons.

Pace and Scope
The course consists of a total of 13 modules which are ~60 to 90 minutes long. The course is divided into two sections:

- Phase 1 or Introductory course which extends from modules 1 to 5 and complements the starter kit
- Phase 2 or the Extension course which includes modules 6 - 13 and complements the extension kit. It is designed to facilitate applications of knowledge, skills, and concepts introduced in modules 1-5.

The course can be facilitated as an immersive experience across two weeks or spread out across a unit/semester.

While it is strongly encouraged to complete the entire curriculum you may also choose to just focus on the first 6 lessons which are an introduction to soft robotics.

Making Learning Visible:
With hands-on courses often the question on everyone's mind is, are the students learning? What are they learning? How do we know that they are learning? This course has embedded strategies that enable students to make their learning visible. Two specific strategies are:

- Concept Mapping: Students create a word cloud using words that come to their mind when they hear the word robot at the start of the course in module 1, next at the end of module 5 and once again after module 12. Comparing all 3 word clouds help in understanding how students' understanding of robots has evolved through the course.

- Design Journaling: In phase 2 as students switch to solving the design challenge they maintain a daily design journal which is an opportunity for them to log what they worked on each day and also reflect on which maker elements they embodied and what they struggled with.

Module Outline:

Sr. No	Title	Description
Pre-Program Student Survey		
Phase 1: Starter Kit		
1	Introduction	Introduces students to robots as devices that can • sense-think and act on their own • be made with rigid and soft materials • materials used to build robots influence the performance of the robot
2	Build a Soft Actuator	Build the soft actuator and learn about silicone, mold making and casting
3	Bio-Inspiration: Learning from Nature	Students are introduced to the idea of bio-inspiration or learning from nature. They compare and contrast the manual gripper with the human hand to understand how we can learn from nature as we design machines
4	Building an Autonomous gripper - Part 1	Build the electronics kit and learn how cables, motors and pulleys can be used to move parts of a robot.
5	Building an Autonomous gripper - Part 2	Build the programming kit and learn about sensing, control. Students are introduced to Arduino programming.
End of Starter Kit Student Feedback		
Phase 2: Extension Kit		
6	Introducing the Engineering Design Process	Students are introduced to the engineering design process, maker mindsets and the soft robotic toolkit competition.
7	Understanding the Problem	Students review the limits of their soft gripper and set a design challenge.
8	Gathering Inspiration	Students observe grippers in nature as well as some man made soft grippers to gather inspiration and understand how the structure of the actuator influences the functional abilities of the gripper.
9	Imagine	Students begin by generating conceptual sketches of multiple ideas. Later, students develop a detailed conceptual sketch of one idea they want to further develop.

10	Plan and Create	Students convert their conceptual sketches into detailed drawings. They make their designs tangible by building prototypes of their designs using simple material.
11	Test and Improve	Students test their new actuators. Based on feedback students build new iterations.
12	Final design	Students build 3D mold for the final design and cast silicone.
13	Share	Students present their final projects and share their learnings/ reflections.
End of Extension Kit Student Feedback		
Post-program Student Survey		

Suggested pacing for block schedule:

Day 1 Conduct Pre-survey with students in control and intervention groups. Module 1	**Day 2** Module 2	**Day 3** Module 3	**Day 4** Module 4	**Day 5** Module 5
Day 6 Module 6	**Day 7** Module 7	**Day 8** Module 8	**Day 9** Module 9	**Day 10** Module 10
Day 11 Module 11	**Day 12** Module 12	**Day 13** Final Showcase & Celebration! Conduct post intervention survey with students in control and intervention groups		