Building Computational Thinking at Top Universities

MathWorks

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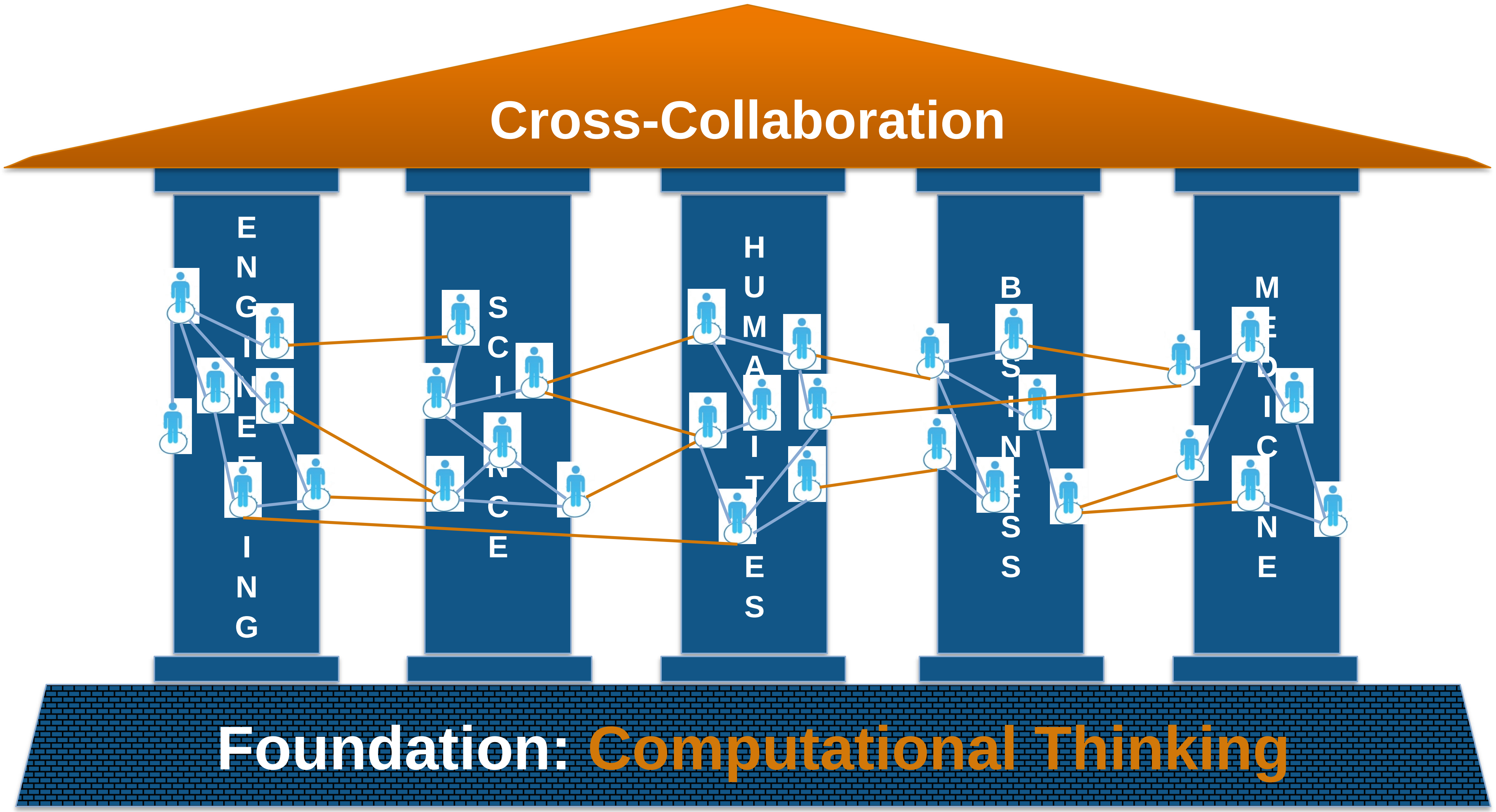


Cross-Collaboration
ENGINEERING
SCIENCE
HUMANITIES
BUSINESS
MEDICINE
Foundation: Computational Thinking

What Is Happening Elsewhere

MOOC

Inverted classroom

Integrated curriculum

Computation

Collaboration

Visualization

On-line learning

Computational Thinking

A Thought Process to Formulate Problems and Solutions

Decomposition

Abstraction

Pattern Recognition

Algorithms

Where Computational Thinking Fits

Computational Thinking

Reading

Writing

Arithmetic

Computational Thinking is Important

Learn to Code + Code to Learn!

"Computational thinking is a fundamental skill for everyone, not just for computer scientists.“

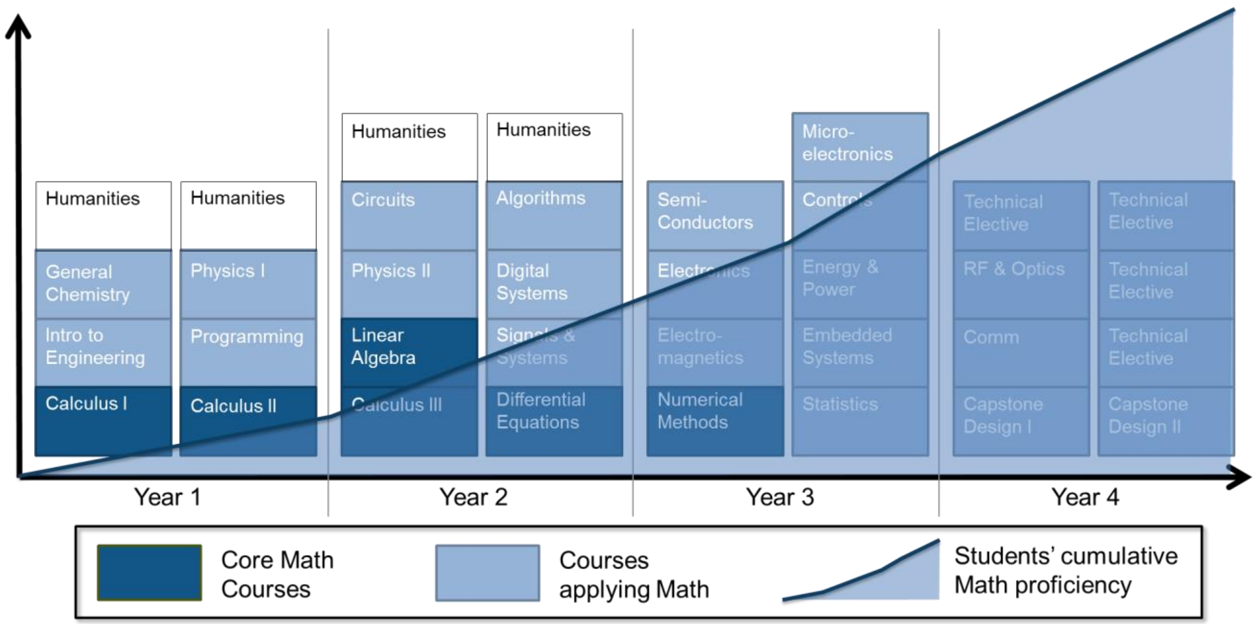
Dr. Jeannette Wing, Vice President of Microsoft Research
Former Department Head of CS at Carnegie Mellon University

“Coding teaches me to think in a logical way”

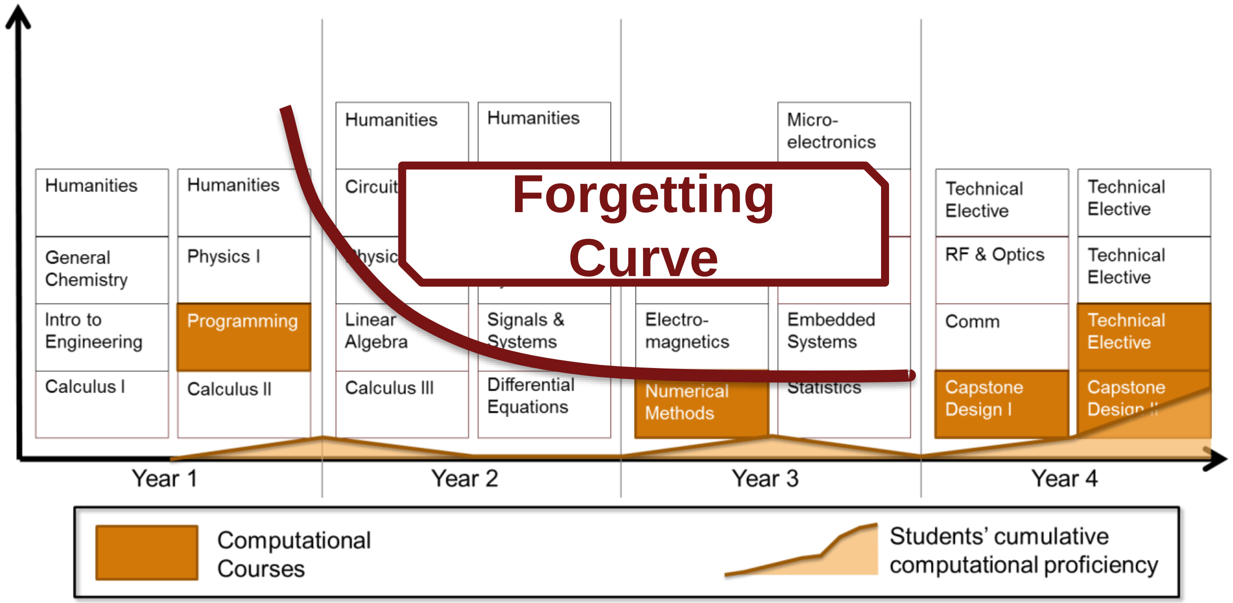
Trinity School high school student
Accepted at MIT

Traditional Approach to Teaching

How Math is introduced in the curriculum

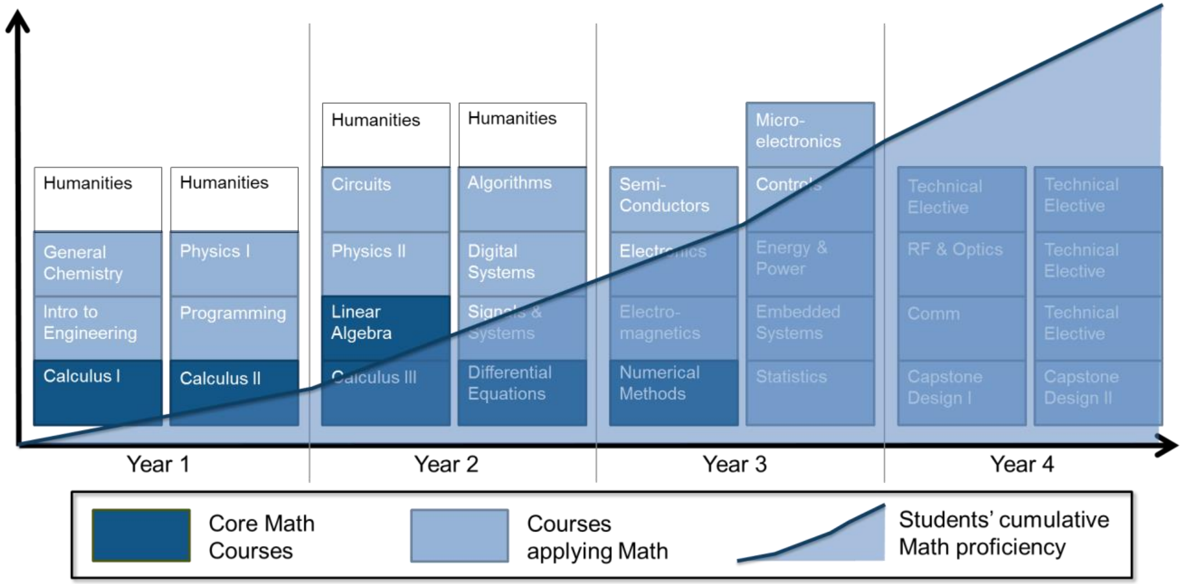


How Computational Thinking is introduced

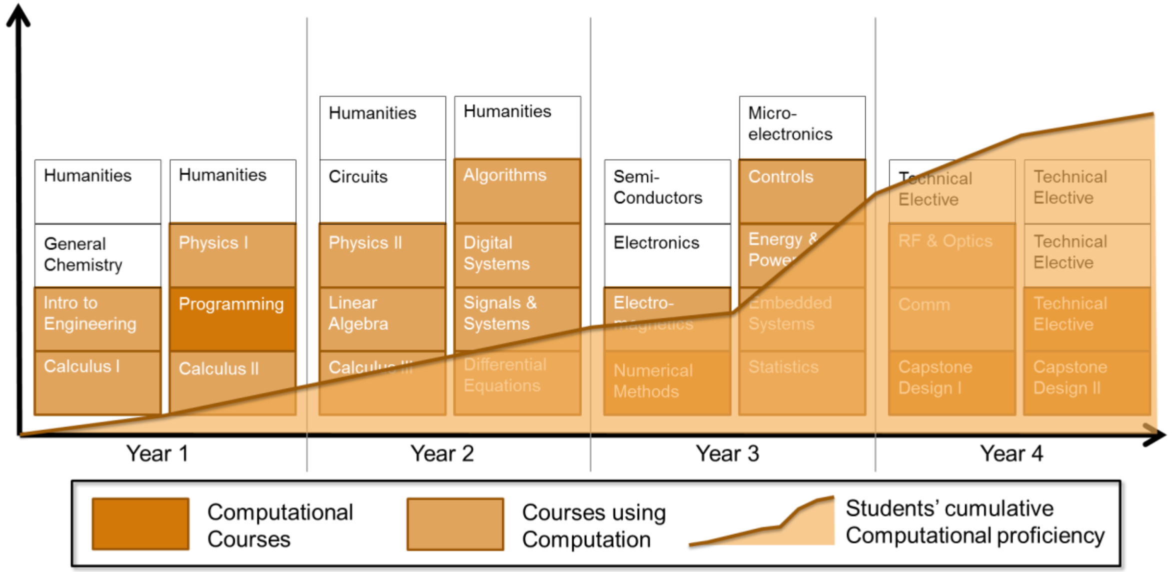


The Future of How Computational Thinking Will be Taught

How Math is introduced in the curriculum



How Computational Thinking could be taught



How Top Universities Build Computational Thinking with MATLAB

1. **Supplementing pen and paper**

   Imperial College

2. **Using on-line learning**

   MIT

3. **Integrating usage across classrooms**

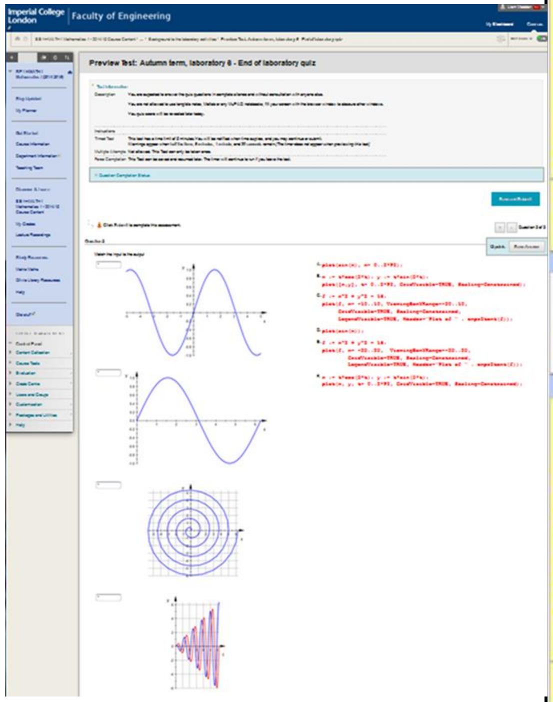
   MIT & University of Cambridge

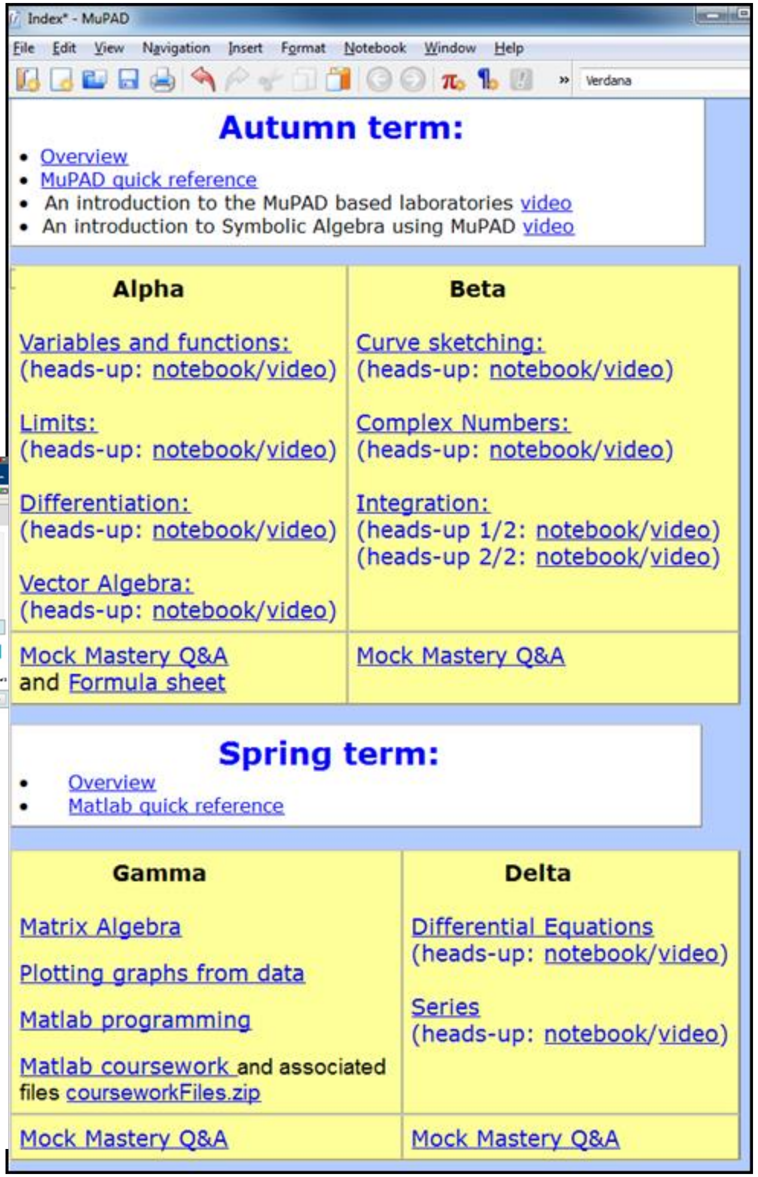
1. Supplementing pen and paper

Visualization

The Mathematics Laboratory
Imperial College London, Bioengineering

1. Lecture (YouTube / live)
2. Pen and paper study group
3. MATLAB laboratory
4. Formal assessment





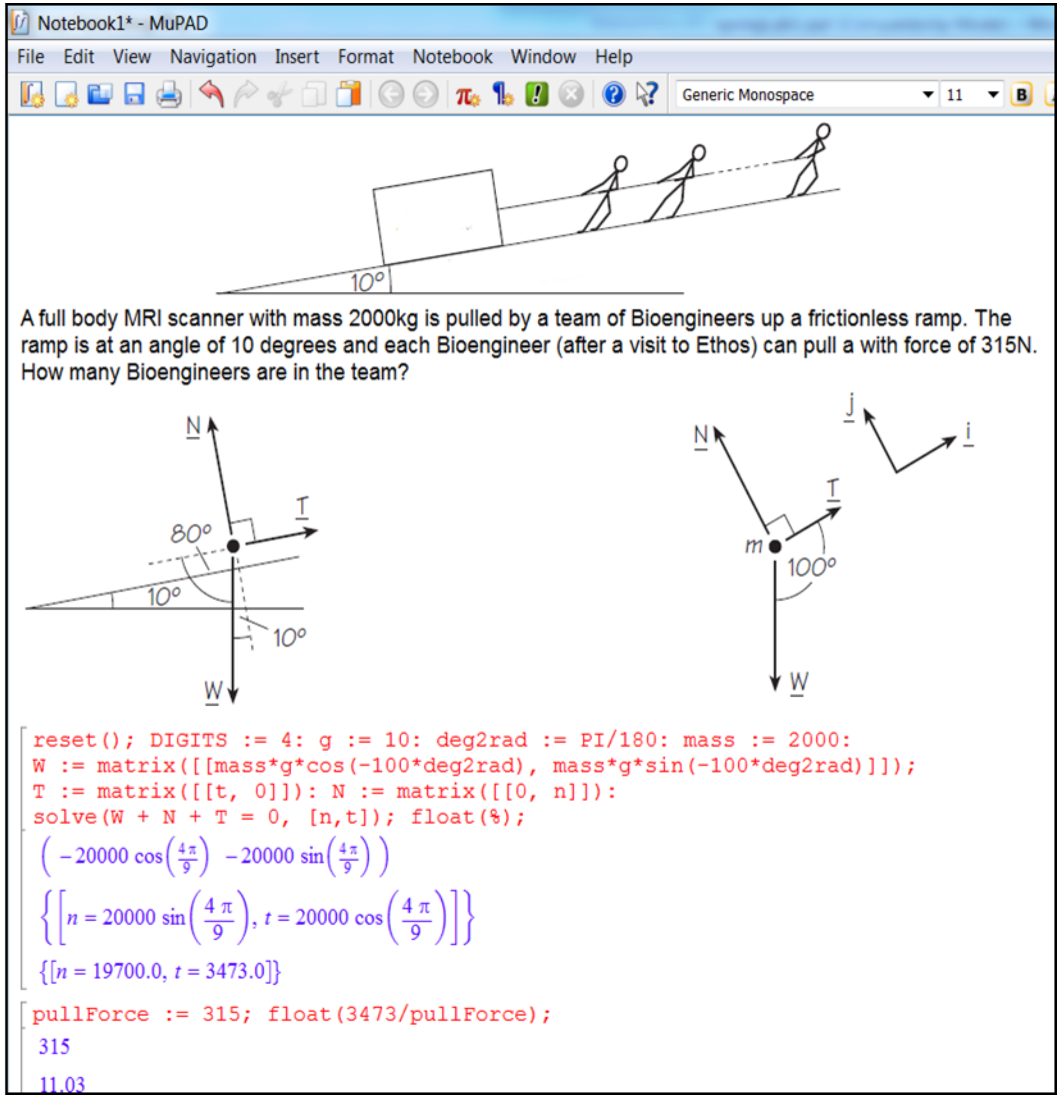
MATLAB to complement Mathematics teaching

- **Brings Mathematics to life**
- **Engagement of brighter students**
- **Reinforcement learning**

From Symbolic to Multi-Paradigm Solutions

- Start with Symbolic Math
- Reinforce hand-calculations
- Move to multi-paradigm solutions for real engineering problems

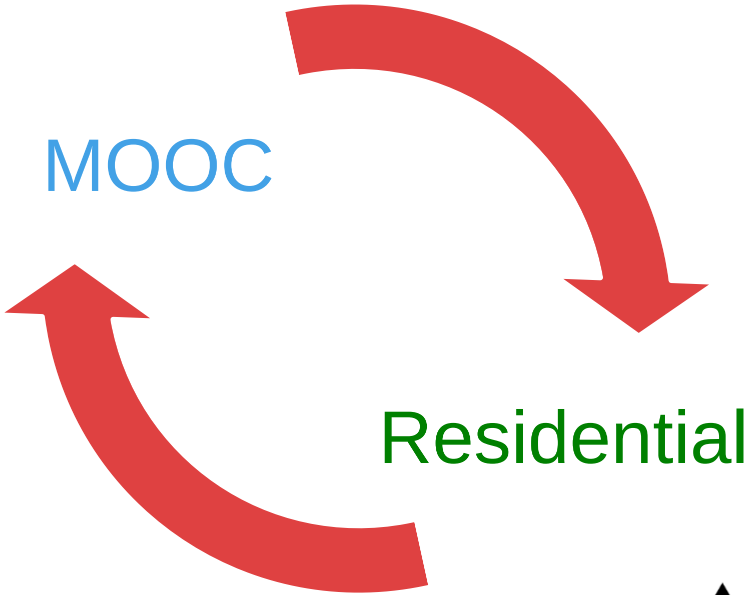
```
>> g = 10, mass = 2000
g =
    10
mass =
     2000
>> m = [cos(degtorad(10)),
        cos(degtorad(100));
        sin(degtorad(10)),
        sin(degtorad(100))]
m =
    0.9848   -0.1736
    0.1736    0.9848

>> inv(m)*[0 ; mass*g]
ans =
   1.0e+04 *
    0.3473
    1.9696

>> ans(1)/315
ans =
   11.0253
```



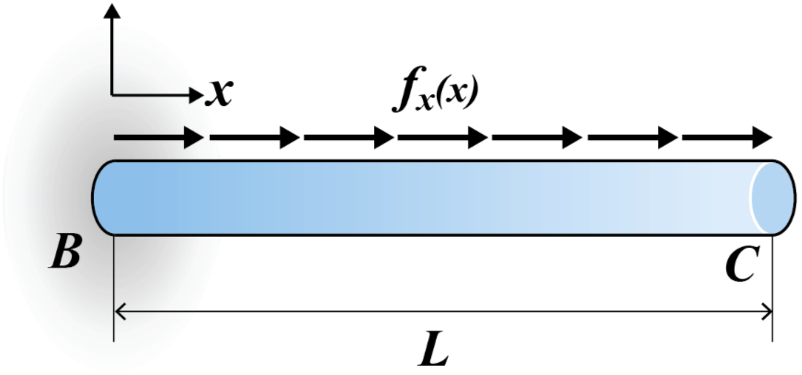
2. Using on-line learning

On-line course

MIT Mechanical Engineering
2.01x Elements of Structures, Required for 2nd year students
[Simona Socrate]()



- Was a paper and pencil class
- Moved the material to edX as a MOOC
- Material is evolving through a constant cycle of residential classes and public MOOC offerings



Different style of learning: Written Lecture Notes

Axisymmetric Shafts in Torsion

Loading Conditions on each Section (x)
Applied loading only around the axis (x) of the shaft.

The only internal resultant at any sections $\perp x$

is the axial torque $T(x)$ 

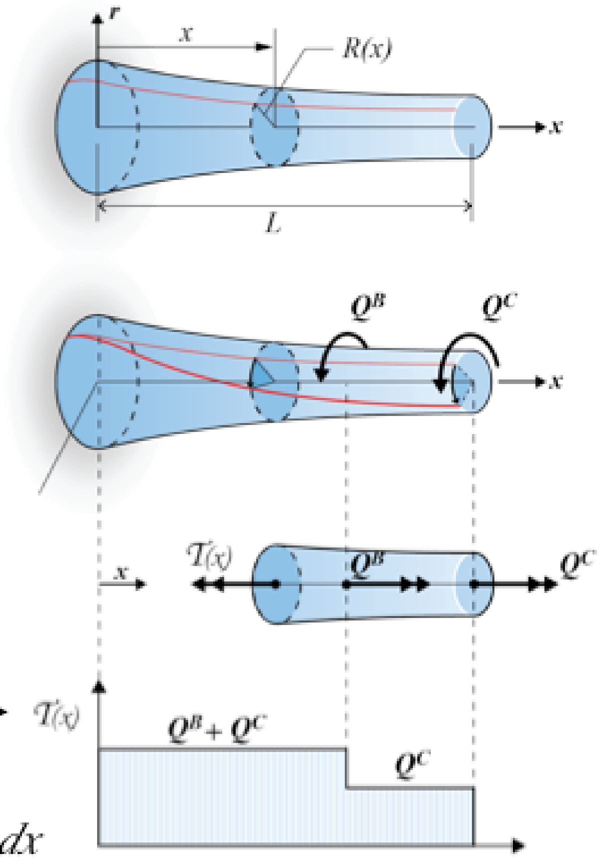
Find $T(x)$ along the bar (**axial torque diagram**) by cutting the bar at x and imposing moment_x equilibrium.

For the example shown, equilibrium at x gives:

for $x<x^B$: $\Sigma M_x = 0 = -T(x)+Q^C+Q^B \rightarrow T(x) = Q^C + Q^B$

for $x>x^B$: $\Sigma M_x = 0 = -T(x)+Q^C \rightarrow T(x) = Q^C$

And the entire axial torque diagram is:

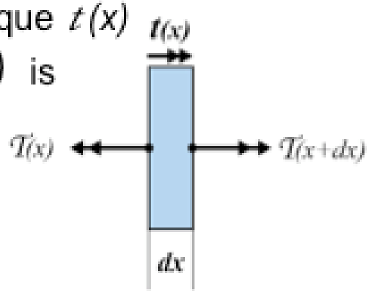


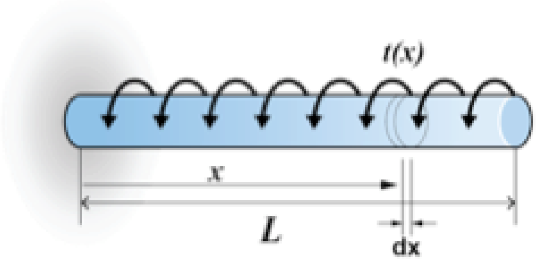
For distributed loading $t(x)$, with $t(x)$ [in (N*m)/m =N]
⊕ with right hand rule along x, obtain the torque $T(x)$ by integrating $t(x)$ along the shaft. For the shaft shown:

$$T(x) = \int_x^L t(x)\,dx$$

The differential relationship between the distributed torque $t(x)$ and the axial resultant $T(x)$ is

$$\frac{dT(x)}{dx} = -t(x)$$





Different style of learning: Short Video Lectures

Concept Questions in reading and video

E6_2_1

(1 point possible)

Obtain a symbolic expression for the effective section stiffness of the shaft, $(GI_p)_{Eff}$, in terms of R_0 and G_0 (enter thes

E6 2 | Torsion of Axisymmetric Shafts | 2.01x Courseware | edX

?

$(GI_p)_{Eff} =$

CHECK

E6_2_2

(1 point possible)

Obtain a symbolic expression for the x-rotation field along the shaft, $\varphi(x)$, in terms of R_0, G_0, L, Q, and x. (Note the direction of x in the figure):

?

$\varphi(x) =$

CHECK

Online recitations

VR7_1a

R7_1A: BENDI

In thi
x-axi

For the bea
$\mathcal{M}(x)$, the
maximum

R7_

$\mathcal{M}(x) =$

(4 pc

$\mathcal{M}(x) =$

$\mathcal{M}^{+}_{\max} =$

CHECK

Start of transcript. Skip to the end.

PROFESSOR: Hi everyone, and welcome back to 2.01x recitation.

In this segment, we're going to do a number of examples of finding the moment diagram for beams under various loading conditions.

So let's get started with a simple one.

So we're just going to have our beam supported by two pins.

So we've got something like this.

Download video

Download transcript .srt

MATLAB Problem Sets

E6_1: SHEAR STRAIN AND SHEAR STRESS IN A COMPOSITE SHAFT
E6_1_2
E6_1_4X

(1/1 point)

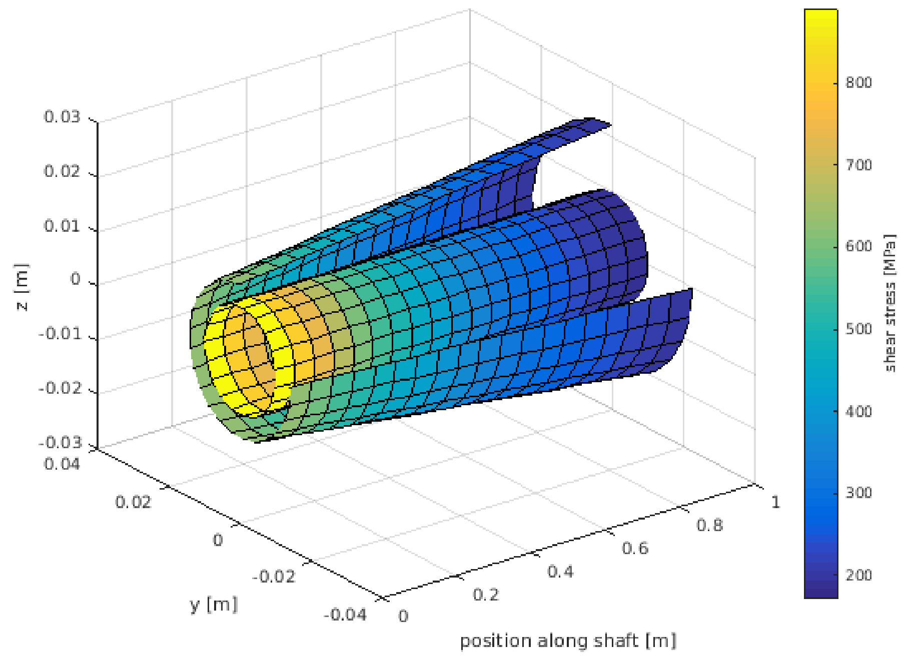
Use the MATLAB window below to verify your solution to part (4) above: obtain the values of the maximum shear stress in the sleeve $\tau_{s,\max}$ and in the core $\tau_{c,\max}$ on each section x, for $0 \leq x \leq L$. For $\tau_{s,\max}$ and $\tau_{c,\max}$ make sure you have the numeric values in MPa, and use corresponding MATLAB variables `tau_c_max` and `tau_s_max` in your script. EXTRA STEP: Try to obtain a plot with both curves, $\tau_{s,\max}$ and $\tau_{c,\max}$ as a function of position x along the shaft (the plotting task is not checked). Do the two curves cross at your predicted value x^*?

```
% Create  variables representing the given quantities
L = 1;                  %  in [m]
R0 = 0.01;              %  in [m]
G0 = 70E9;              %  in [Pa]
G0 = 70E9;              %  in [Pa]
T = 3500;               %  in [N·m]
x=linspace(0,L,20);      % a vector of (20) x positions along the shaft

% Your code below
% re-use the same script of part 2x.....

RA = sqrt(2)*R0;       %outer radius at A
RB = sqrt(5)*R0;       %outer radius at B
R=RA+(RB-RA)*x/L;      % a vector with outer radius of the shaft at each x position
Gc=2*G0;               % shear modulus of the core
Gs=G0;                 % shear modulus of the sleeve
```

NOTE: this is probably the MOST challenging problem you have seen so far. I strongly suggest you do the three recitation problems before you try this one. The MATLAB scripts are quite long, and use tricks you might not have seen before, but they are quite nifty and you might like them! Try doing as much work as you can before you reveal the solutions, and try playing with the MATLAB answer scripts to understand how they work.

Correct

Figure 1



CHECK RESET SHOW ANSWER

3. Integrating usage across classrooms

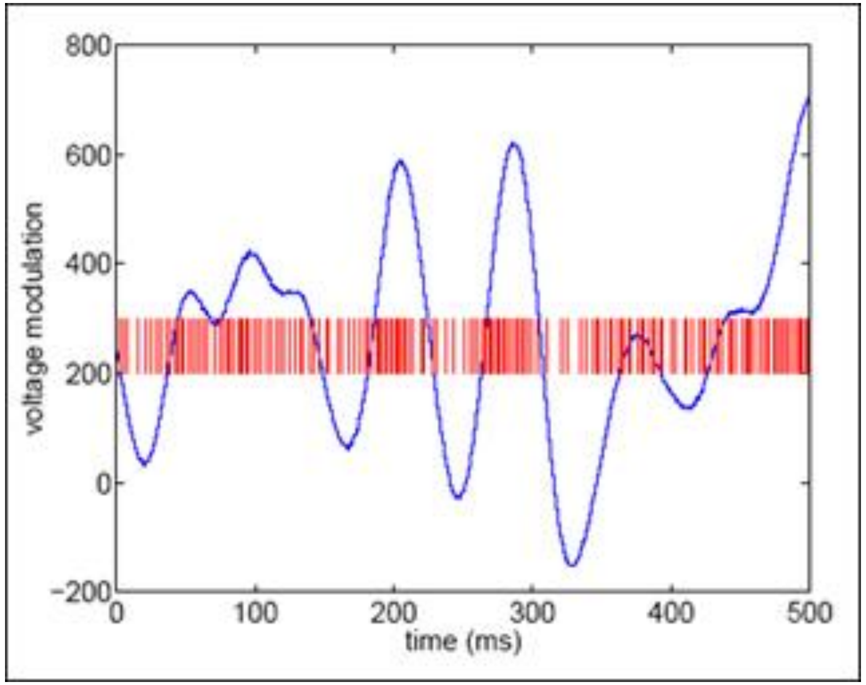
Integrated curriculum

MIT – Department of Brain and Cognitive Sciences

- Request from industry and graduate research
  - None of undergraduate courses taught computation
  - Moved to introduce quantitative material earlier

- Hired instructor for a transition to more computation (MATLAB) in courses
  - 9.40 Introduction to Neural Computation (required UG)
  - 9.54 Computational Aspects of Biological Learning (elective UG)
  - 9.011 Systems Neuroscience (required G – level setting incoming student knowledge)

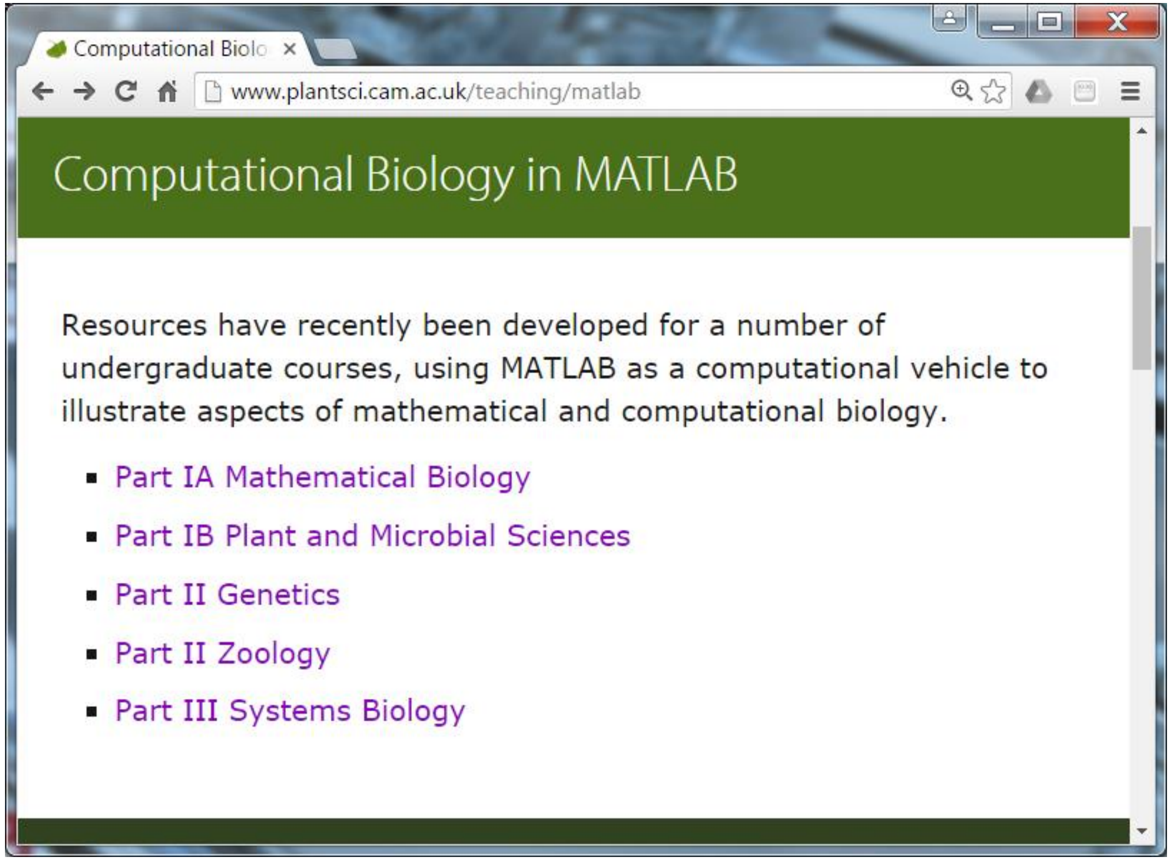
- MATLAB Bootcamp, office hours



Taken from: MIT OCW 9.29

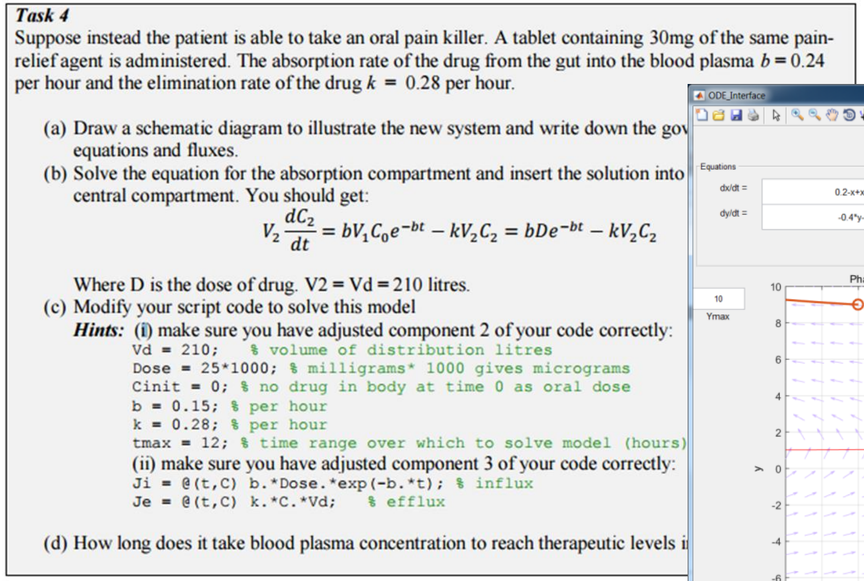
University of Cambridge Biological Sciences

- Natural Science Course at Cambridge Biological Sciences stream
  - MATLAB Course complement Math (Year 1)
  - Reinforcement & math modelling in Plant & Microbial Science (Year 2)
  - Genetics and Zoology using the modelling skills (Year 3)
  - Systems Biology – Modelling techniques (Year 4 or Masters)



Laboratory Exercises

- Word problems
- Apps
- Scripts & functions
- Visualizations



Task 4

Suppose instead the patient is able to take an oral pain killer. A tablet containing 30mg of the same pain-relief agent is administered. The absorption rate of the drug from the gut into the blood plasma $b = 0.24$ per hour and the elimination rate of the drug $k = 0.28$ per hour.

(a) Draw a schematic diagram to illustrate the new system and write down the gov equations and fluxes.

(b) Solve the equation for the absorption compartment and insert the solution into central compartment. You should get:

$$V_2 \frac{dC_2}{dt} = bV_1C_0e^{-bt} - kV_2C_2 = bDe^{-bt} - kV_2C_2$$

Where D is the dose of drug. V2 = Vd = 210 litres.

(c) Modify your script code to solve this model

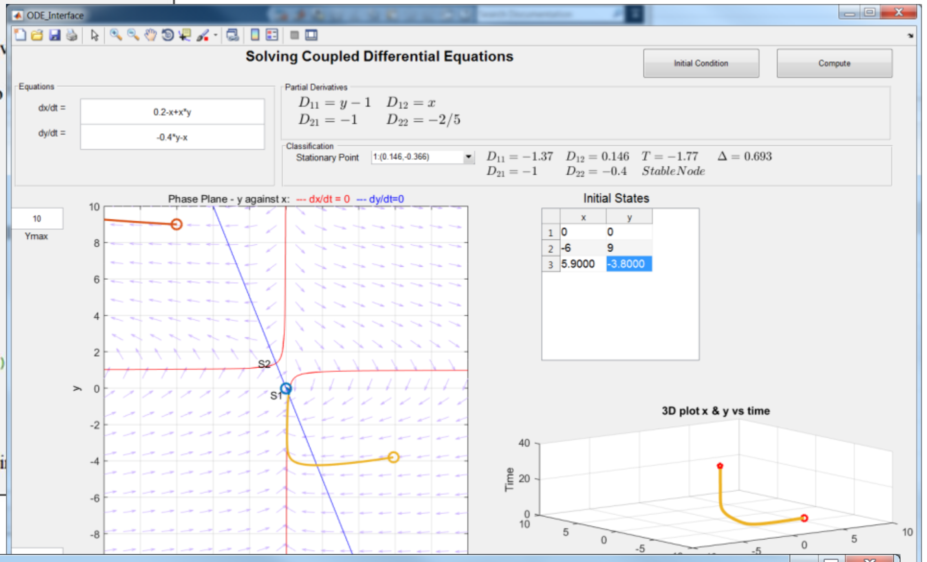
Hints: (i) make sure you have adjusted component 2 of your code correctly:

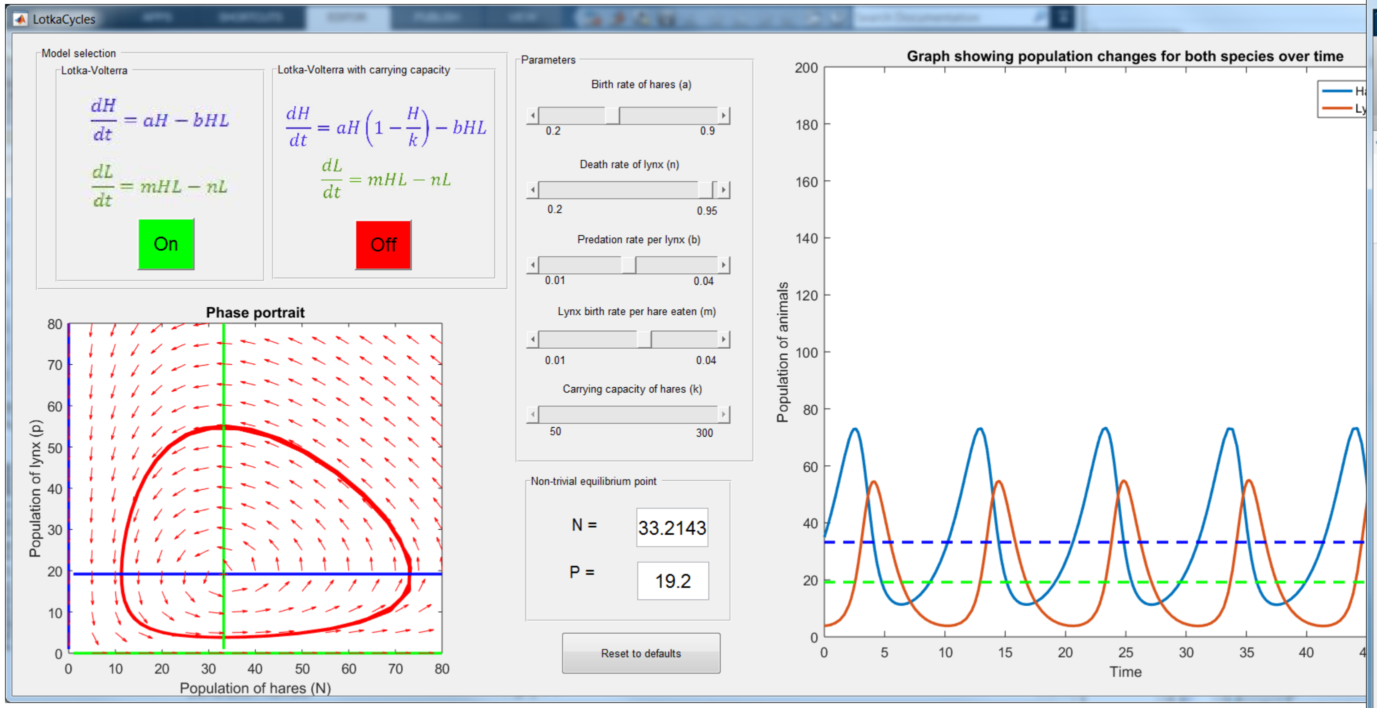
```
Vd = 210;    % volume of distribution litres
Dose = 25*1000; % milligrams* 1000 gives micrograms
Cinit = 0; % no drug in body at time 0 as oral dose
b = 0.15; % per hour
k = 0.28; % per hour
tmax = 12; % time range over which to solve model (hours)
```

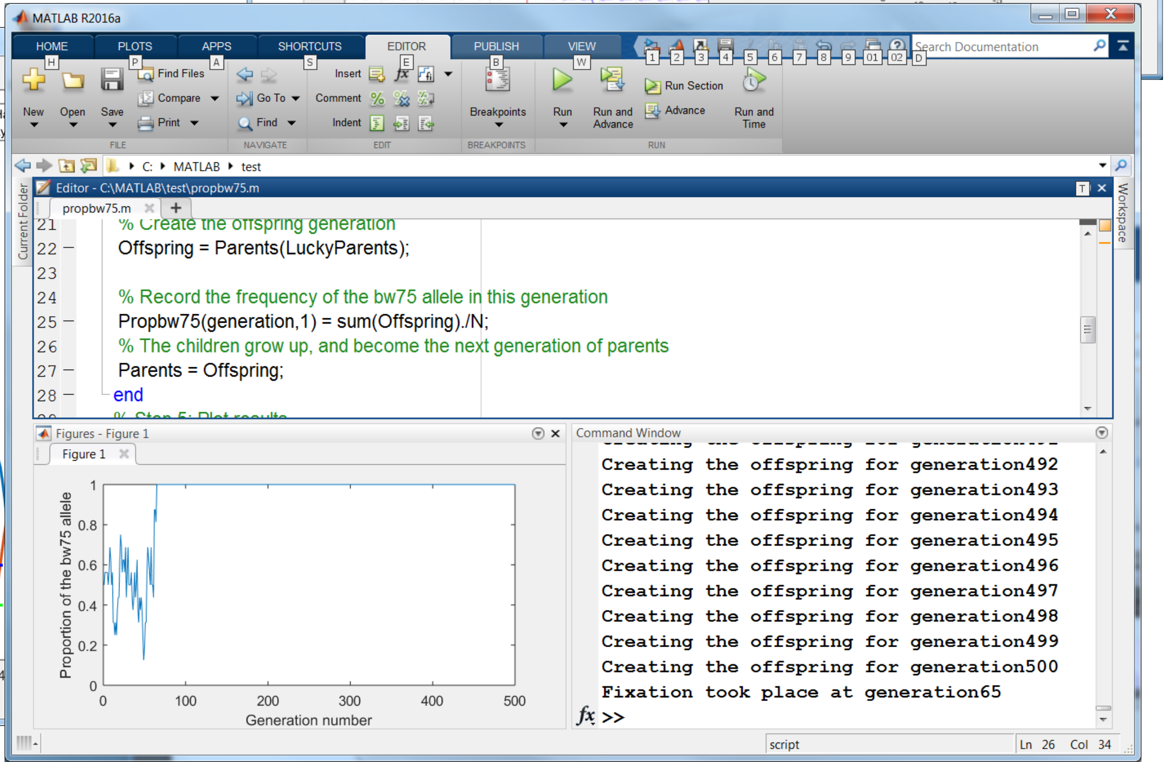
(ii) make sure you have adjusted component 3 of your code correctly:

```
Ji = @(t,C) b.*Dose.*exp(-b.*t); % influx
Je = @(t,C) k.*C.*Vd;    % efflux
```

(d) How long does it take blood plasma concentration to reach therapeutic levels i







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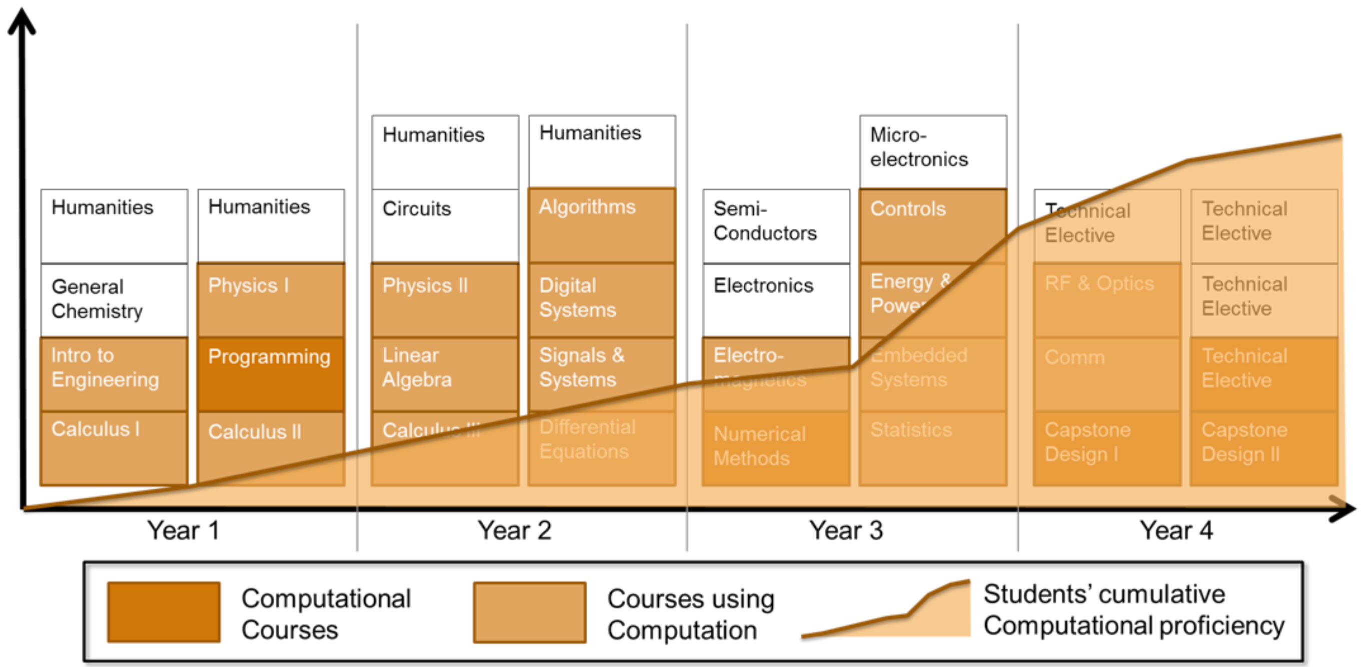
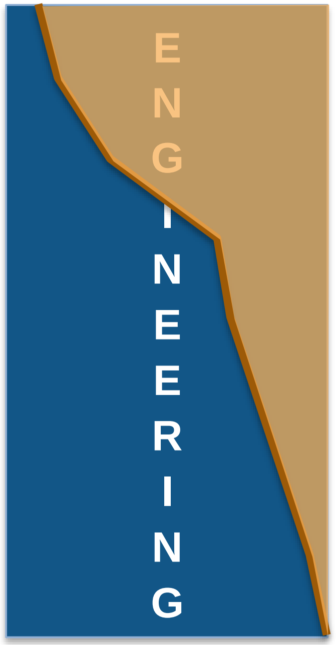
Integrated Curriculum Builds Depth within the Domain

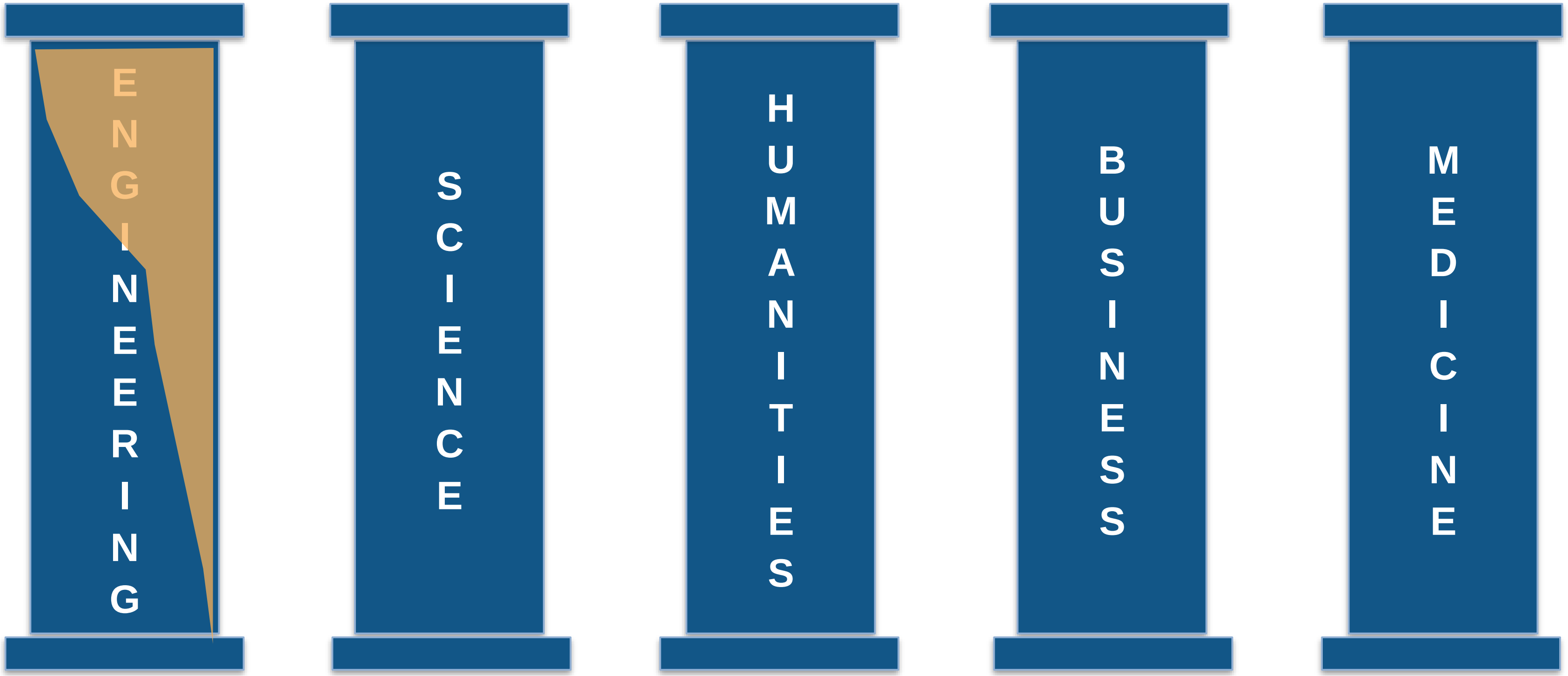
What about Breadth?





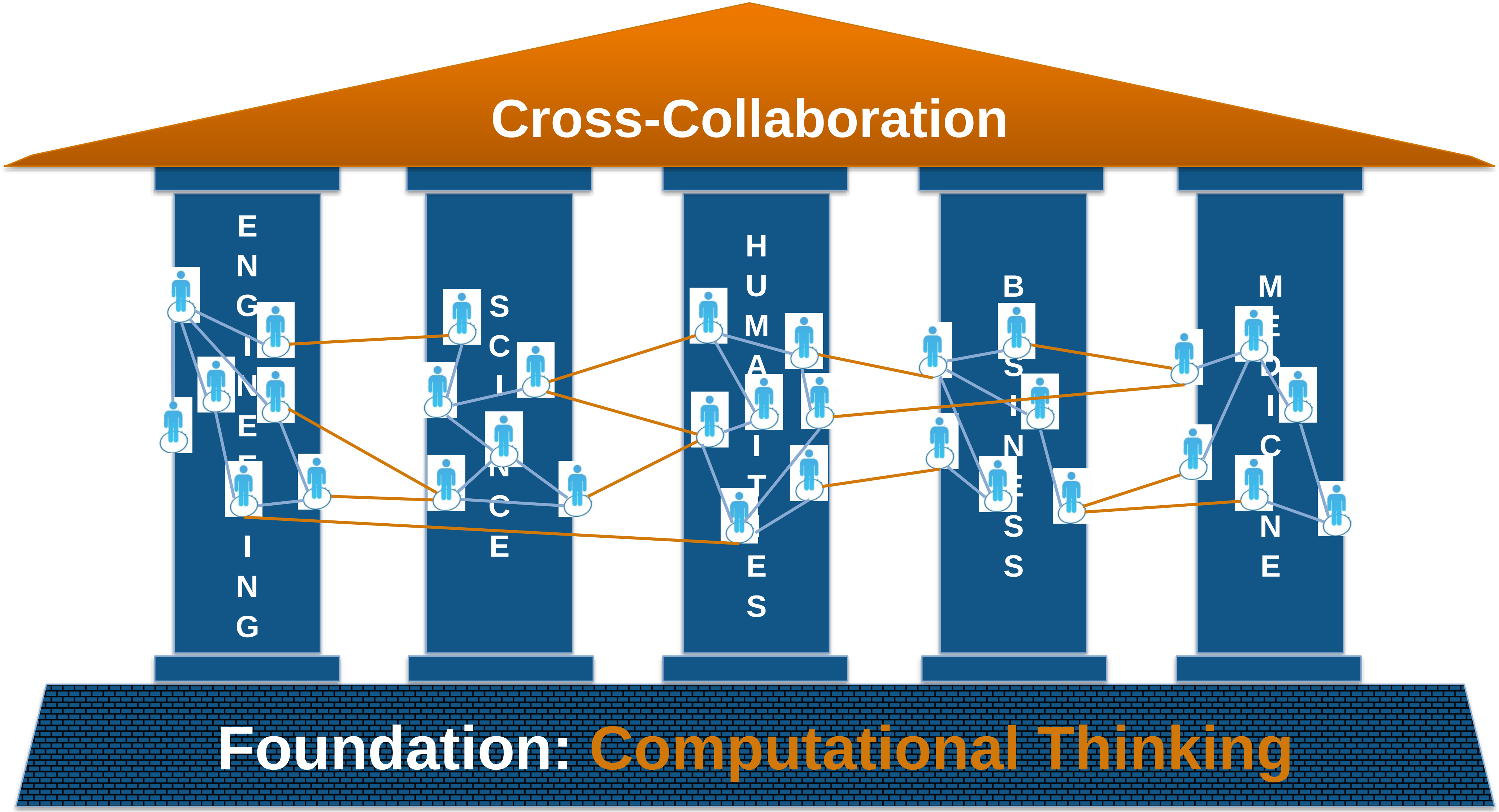
Is This Just About Engineering?

Schools and Colleges are Siloed by Nature



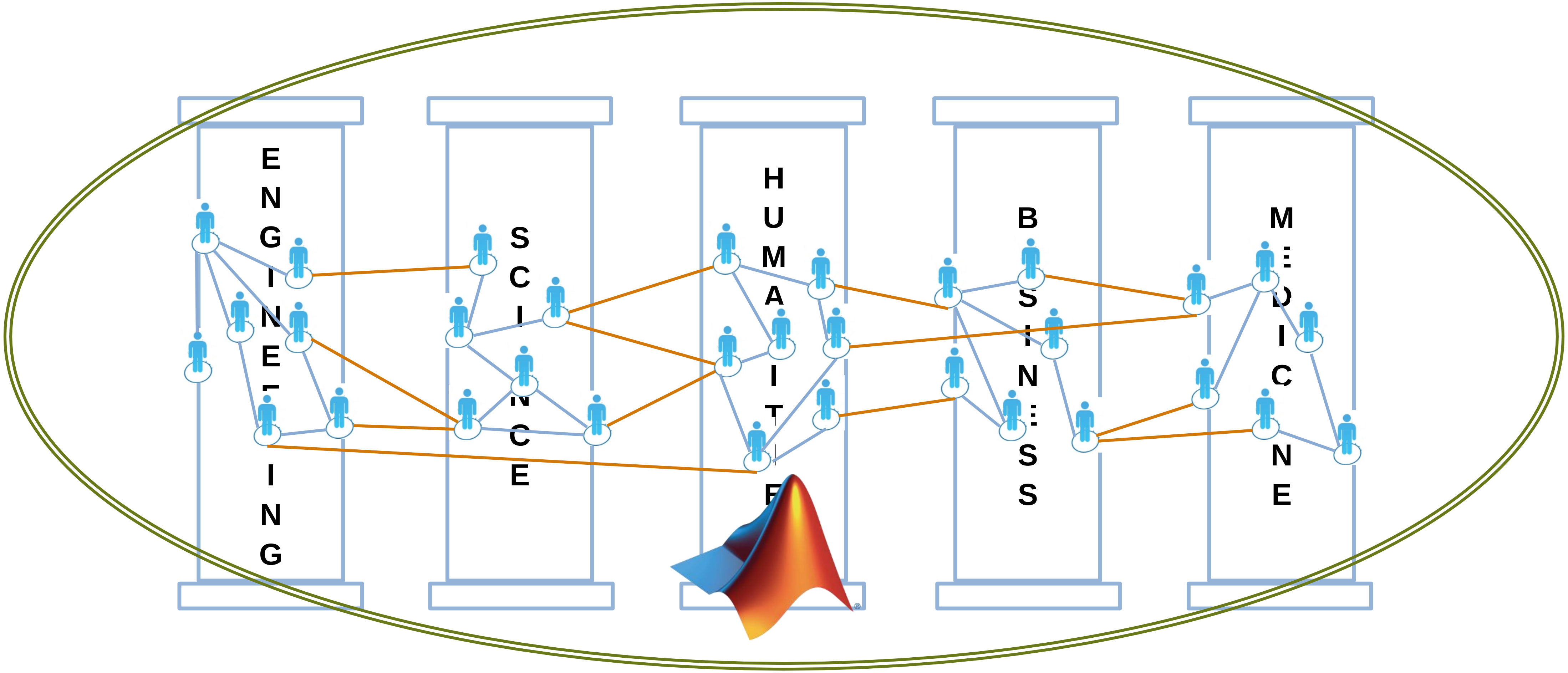
Real World Problems Are Multidisciplinary and Require Collaboration across Domains

What if Computational Thinking Was Commonplace?



Computational Thinking – One Common Language

Integrated Curriculum → Integrated Campus



MATLAB Enabled Campus for Everyone, Anywhere