

*The impact of infusing
computation and visualization
into introductory physics
subjects*

*Kyle Keane, Michelle Tomasik, Anna Musser,
Lauren Berk, and Andrea Griffin*

View this course as:

Course Textbook

Mechanics

Audit Access
You lose all a

- > Course Information
- > Prerequisite Math and Sur
- > Week 1: Kinematics
- > Week 2: Newton's Laws
- > Week 3: Circular Motion
- > Week 4: Drag Forces, Constraints and Continuous Systems
- > Exam
- > Exit Survey

Mary wants to throw a ball straight up and then hit it with a second ball. She wants the balls to collide at height $h=10.0$ m. Assume that the balls are identical and that the balls have a negligible radius. Take $g=9.8$ m/s². The balls are equal.

Enter your answers to

(a) How long does it take the balls to collide?

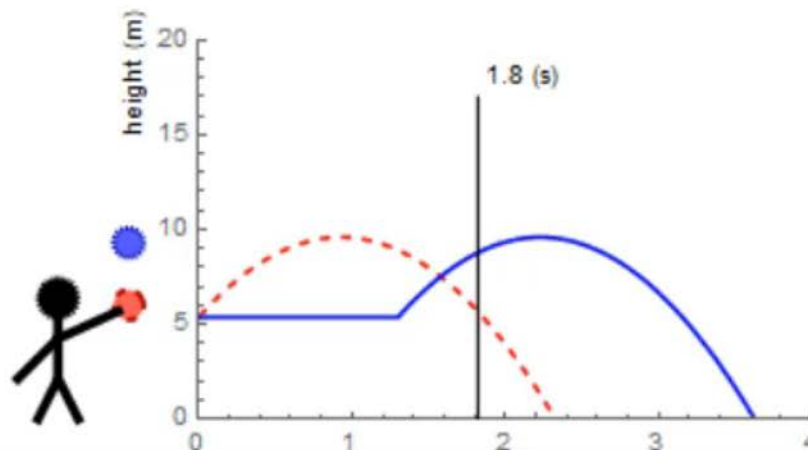
(b) Find the initial speed of the balls.

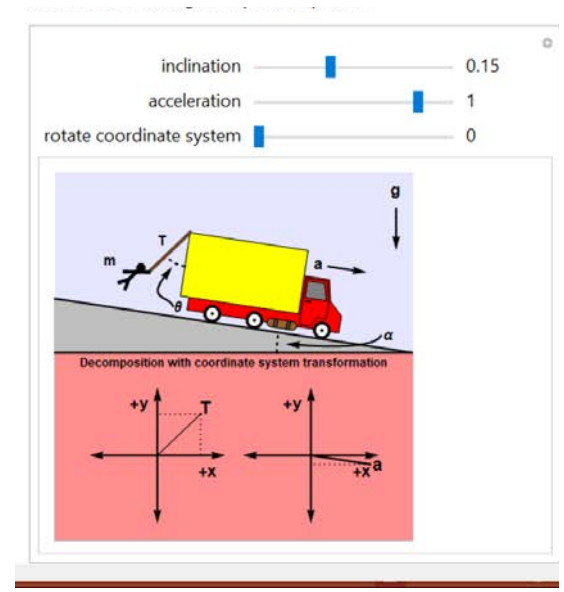
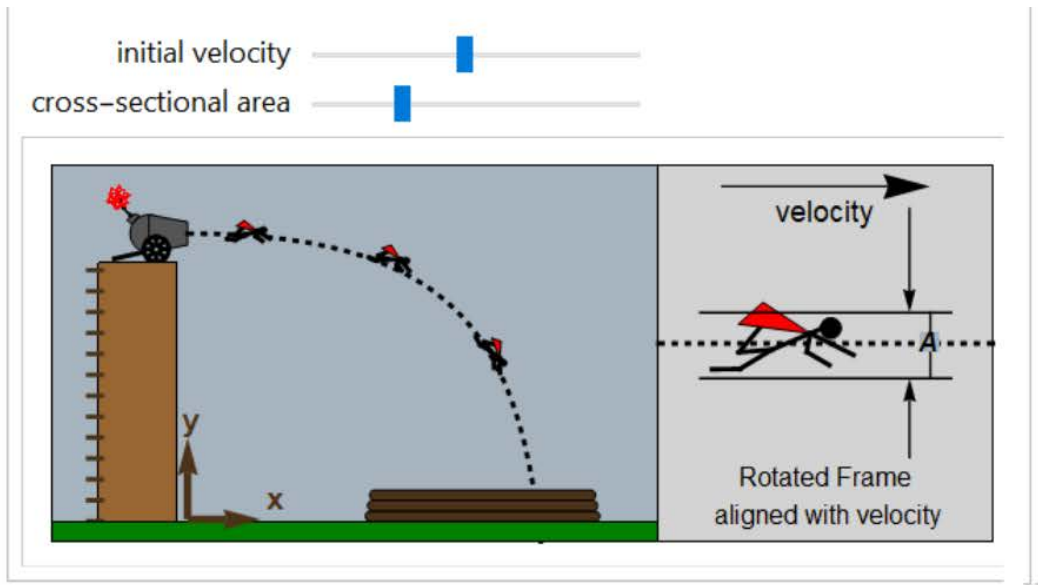
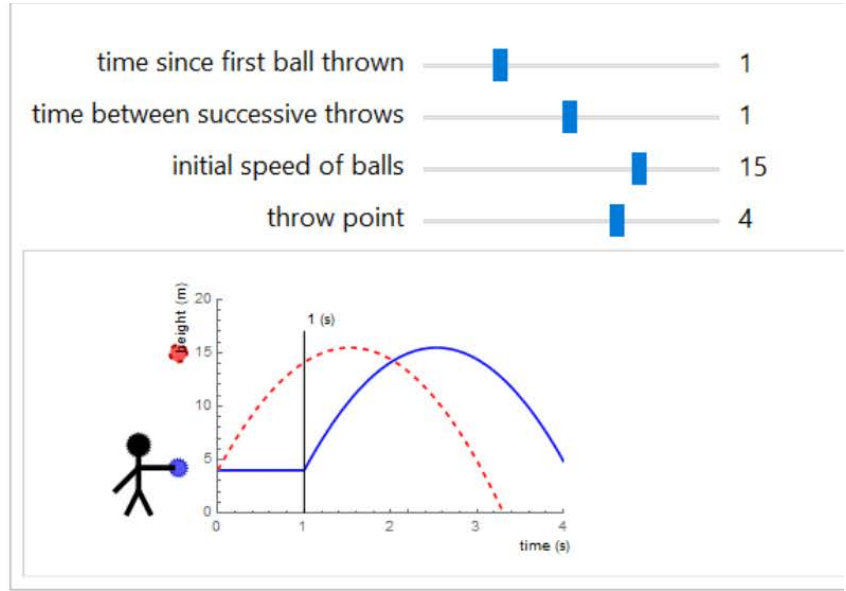
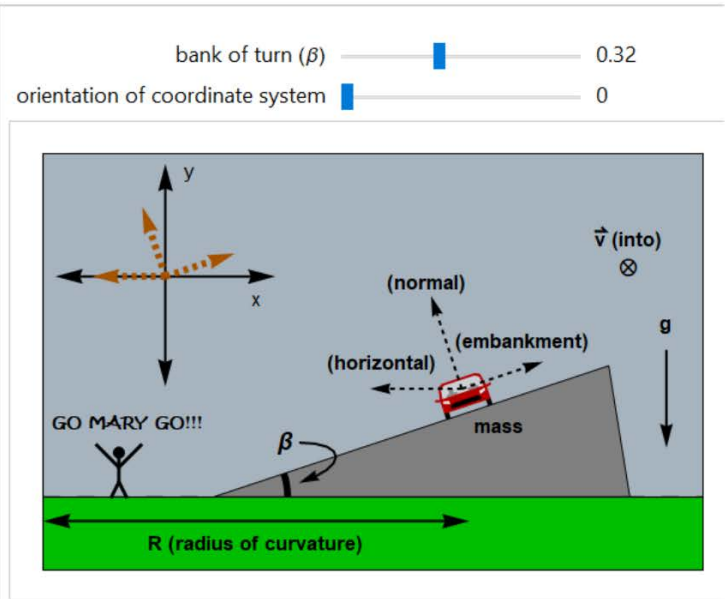
time since first ball thrown 1.82

time between successive throws 1.3

initial speed of balls 9.1

throw point 5.36





We are Educators and Scientists...

- Dr. Kyle Keane
Research Scientist
- Dr. Michelle Tomasik
Digital Learning Scientist
- Anna Musser
Research Methodologist
- Andrea Griffin
Software Engineer
- Lauren Berk
Data Scientist



Solution By Hand, By Code, or By Visualization

Mary wants to throw a ball s
at height $h=10.0$ m above the

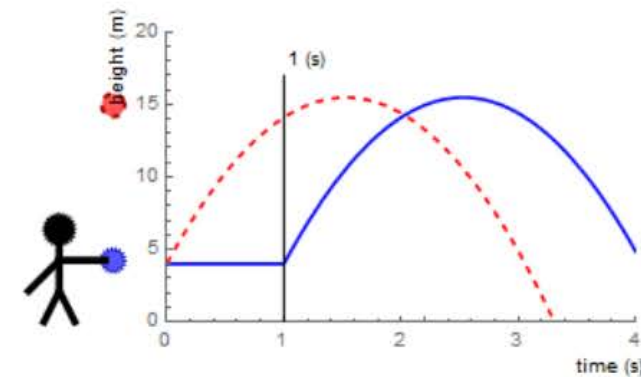
ay, April 30, 2019 1:23 AM

$$\text{Solve} \left[v_0 t + \frac{1}{2} g t^2 == v_0 (t + \Delta t) + \frac{1}{2} g (t + \Delta t)^2, t \right]$$

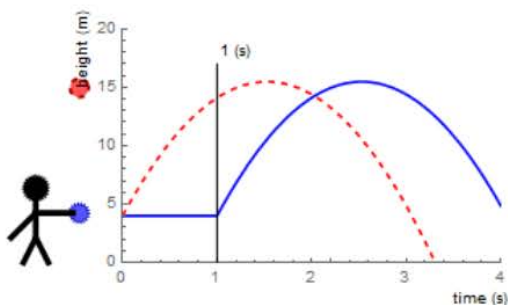
$$\left\{ \left\{ t \rightarrow \frac{-g \Delta t - 2 v_0}{2 g} \right\} \right\}$$

$y_1(t) = v_1(t) \sin(\theta_1)$
 $\theta_0 = 90^\circ$
 $y_1(t) = v_0 t - \frac{1}{2} g t^2$
 $y_2(t + \Delta t) = v_0(t + \Delta t)$
Solve for t when $y_1(t) = y_2(t + \Delta t)$

time since first ball thrown 1
time between successive throws 1
initial speed of balls 15
throw point 4



time since first ball thrown 1
 time between successive throws 1
 initial speed of balls 15
 throw point 4



(a)

time between successive throws 1
 initial speed of balls 15
 throw point 4

	time since first ball was thrown (s)									
	0.	0.5	1.	1.5	2.	2.5	3.	3.5	4.	
Height of first ball (m)	4.	10.3	14.1	15.5	14.4	10.8	4.85	0	0	
Height of second ball (m)	4	4	4.	10.3	14.1	15.5	14.4	10.8	4.85	

Here are some related questions you can consider, but you will not be graded on these.

- When do the balls collide if they are thrown 0.5 seconds apart from 2 meters high at a speed of 5 m/s?
- Does the height of the throw point matter? Why or why not?

Click on each of the following blocks of code hold the SHIFT key while hitting the ENTER key to compute the result of running the following Wolfram Language code

(*CLICK HERE AND HOLD SHIFT WHILE PRESSING ENTER TO RUN THE CODE*)

(*define two equations*)

$$\text{eq1} = 2 + v * t - 2 t^2$$

$$\text{eq2} = 2 + v (t - 2) - 2 (t - 2)^2$$

$$2 - 2 t^2 + t v$$

$$2 - 2 (-2 + t)^2 + (-2 + t) v$$

(*CLICK HERE AND HOLD SHIFT WHILE PRESSING ENTER TO RUN THE CODE*)

(*set them equal and solve*)

```
solveThis = FullSimplify[eq1 == eq2]
```

```
solution = First@Solve[solveThis, t]
```

$$4 t == 4 + v$$

$$\left\{ t \rightarrow \frac{4 + v}{4} \right\}$$

(*CLICK HERE AND HOLD SHIFT WHILE PRESSING ENTER TO RUN THE CODE*)

(*substitute that solution back into the equation and solve for the remaining variable*)

```
substitutedValues = ReplaceAll[10 == eq1, solution]
```

```
FullSimplify@Solve[substitutedValues, v]
```

$$\frac{1}{4} v (4 + v) - \frac{1}{8} (4 + v)^2$$

$$\{ 4 \sqrt{5} \}, \{ v \rightarrow 4 \sqrt{5} \}$$

2x2 Factorial Design

Group 0 - Control: Students are given traditional PSET questions, which are considered standard practice for undergraduate physics courses.

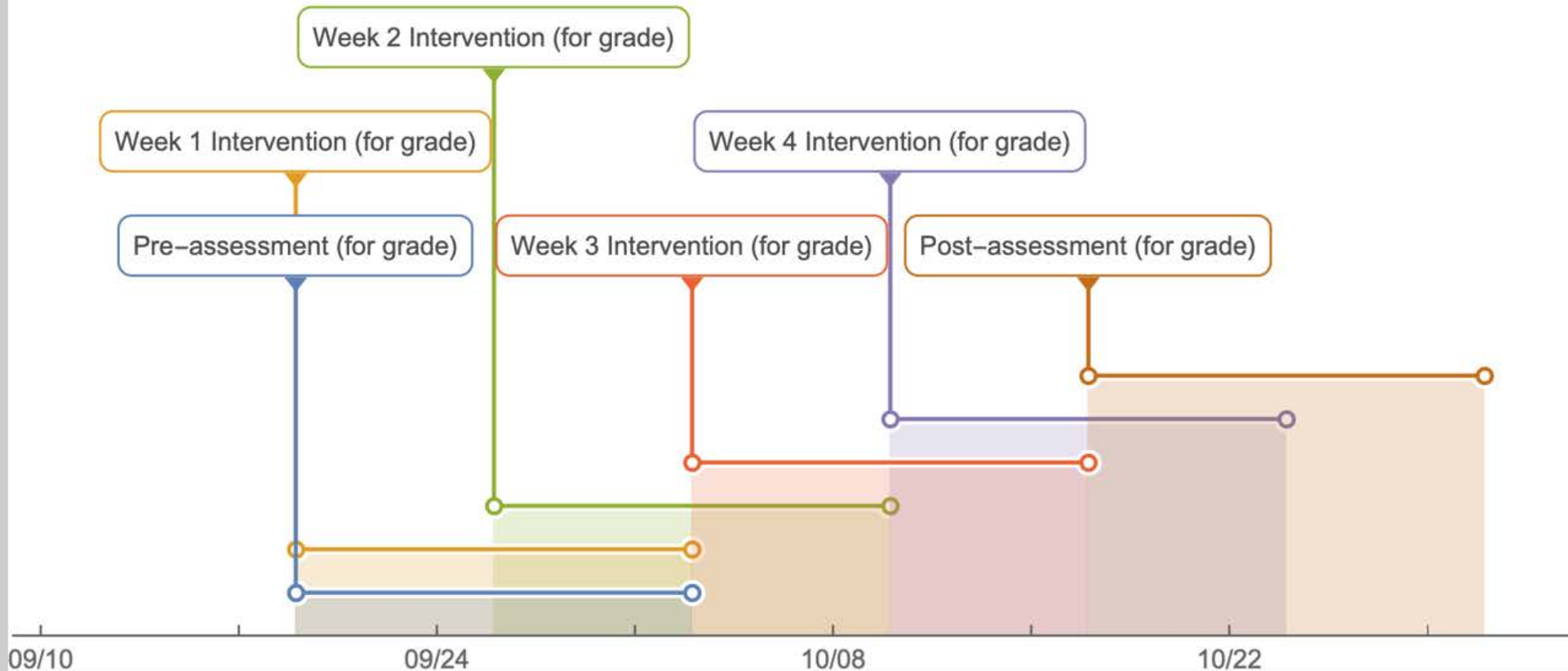
Group 1 - P+V: Students are instructed to modify pieces of code to complete computer PROGRAMMING tasks to solve physics problems by creating VISUAL WIDGETS designed to reinforce physics concepts.

Group 2 - P+N: Students are instructed to modify pieces of code to complete computer PROGRAMMING tasks to solve physics problems by creating NON-VISUAL WIDGETS designed to reinforce physics concepts.

Group 3 - Q+V: Students are given the same VISUAL WIDGETS as Group 1, but they are asked to answer additional QUESTIONS that require them to engage with the widgets.

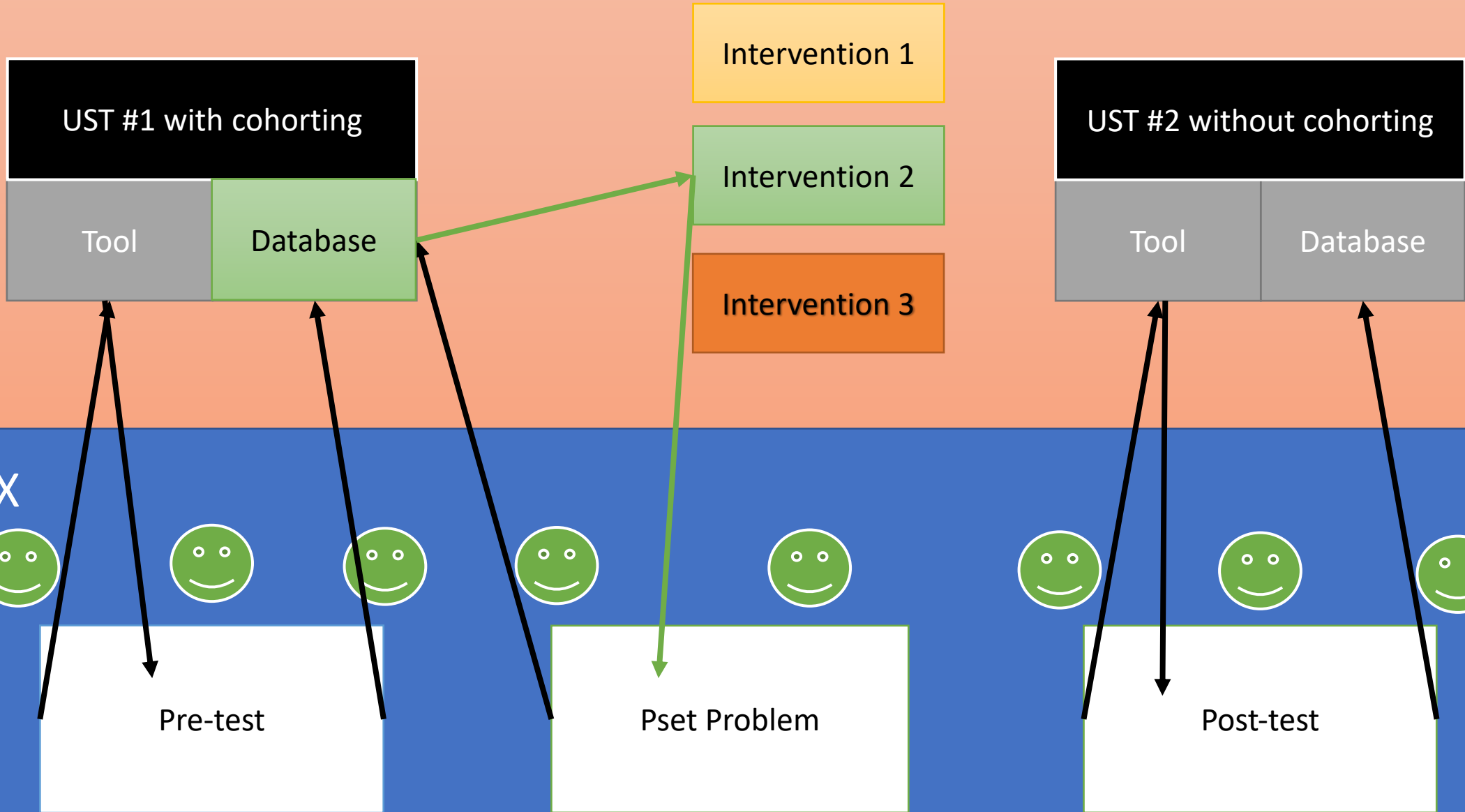
Group 4 - Q+N: Students are given the same NON-VISUAL WIDGETS as Group 2, but they are asked to answer additional QUESTIONS that require them to engage with the widgets.

Sequencing in an Asynchronous Course



In practice, we allowed students to work on each part of the course past the due dates as this was the practice of the rest of the course, however we were diligent to be sure those used in the study followed the intended path of the experiment.

Wolfram Cloud



Pre-test and Balancing Cohorts

- Demographics
- Physics
- Visualization
- Computer
- Self Assessment

As we mentioned earlier, we took an algorithmic approach to assign participants to treatment groups, using dynamic allocation. The covariates we selected to balance were:

- “WL” indicates whether a student has previous experience with the Wolfram Language.
- “Lang” indicates whether a student has other computer programming experience
- “Complete” measures the likelihood of a student completing the course
- “Hours” measures the number of hours per week the students anticipate they will be able to dedicate to the course
- “Support” indicates whether a student has someone such as a friend or family member available to them who can help them with the course
- “Physics” indicates the student’s prior physics knowledge, as measured by the FCI questions asked during the pre-test.
- “Consc” is the conscientiousness score from the Five Factor personality model, and may correlate with a student’s ability to follow-through on their intentions to complete the course.

We gave the Physics pre-test score a weight of four times the weights of the other covariates to reflect its importance and ensure that balancing the Physics covariate was a higher priority in the algorithm.

Preliminary Results - Attrition

One of the survey questions from the beginning of the course asked how likely the students were to complete the course. To begin the analysis of our data, we looked at how predictive this question was of attrition or completion of the course.

How likely are you to complete this <u>course</u> :	Unlikely	Maybe	Likely	I will
Attrition rate:	85.7%	88.2%	82.6%	79.7%

Because we used this survey question as a covariate in the dynamic assignment of participants to treatment groups, we were able to protect against drastically different final sample sizes across treatment groups.

Preliminary Results

Effect of Intervention

Non-standard Tools

Predictive of Change in Standard Assessments?

group	count	Physics	Spatial	CS
0 - Control	14	3.86	3.64	2.50
1 - Viz + coding	16	4.00	3.94	2.56
2 - Just coding	7	4.43	3.00	2.57
3 - Just viz	12	4.42	4.00	3.00
4 - Neither	11	3.45	3.64	2.55
0, 2, 4 - No viz	32	3.84	3.50	2.53
1, 4 - Viz	28	4.18	3.96	2.75
0 coding	37	3.92	3.76	2.68
ing	23	4.13	3.65	2.57

**Not Significant Due to
Insufficient Sample Size**

When we measured the effect of the interventions was using an Analysis of Variance (ANOVA) approach, we found no significant results. We first performed a one-way ANOVA test, treating each treatment group as distinct, and obtained p-values for Physics, Spatial, and CS scores of 0.992, 0.831, and 0.659 respectively. We also performed a factorial ANOVA analysis, which yielded for every combination of groups and final scores, p-values above 0.1. While these results are not statistically significant, they are directionally consistent with our original hypothesis, and we believe with a larger sample size in future trials, we will be able to find significant results.

Preliminary Results

Effect of Intervention

Non-standard Tools

Predictive of Final Grade?

We also considered non-standardized tools In order to measure the benefits of these interventions on the students in 8.01x. Instead of taking the post-tests in physics, spatial reasoning, and computer science as our metrics, we looked at the final course grades of the students in each group, and again performed descriptive and ANOVA analysis.

**Not Significant Due to
Insufficient Sample Size**

Treatment Group	Count	Average Grade
0 - Control	14	82%
1 - Viz + coding	16	89%
2 - Just coding	7	85%
3 - Just viz	12	89%
4 - Neither	11	94%
0, 2, 4 - No viz	32	87%
1, 4 - Viz	28	89%
0, 3, 4 - No coding	37	88%
1, 2 - Coding	23	88%

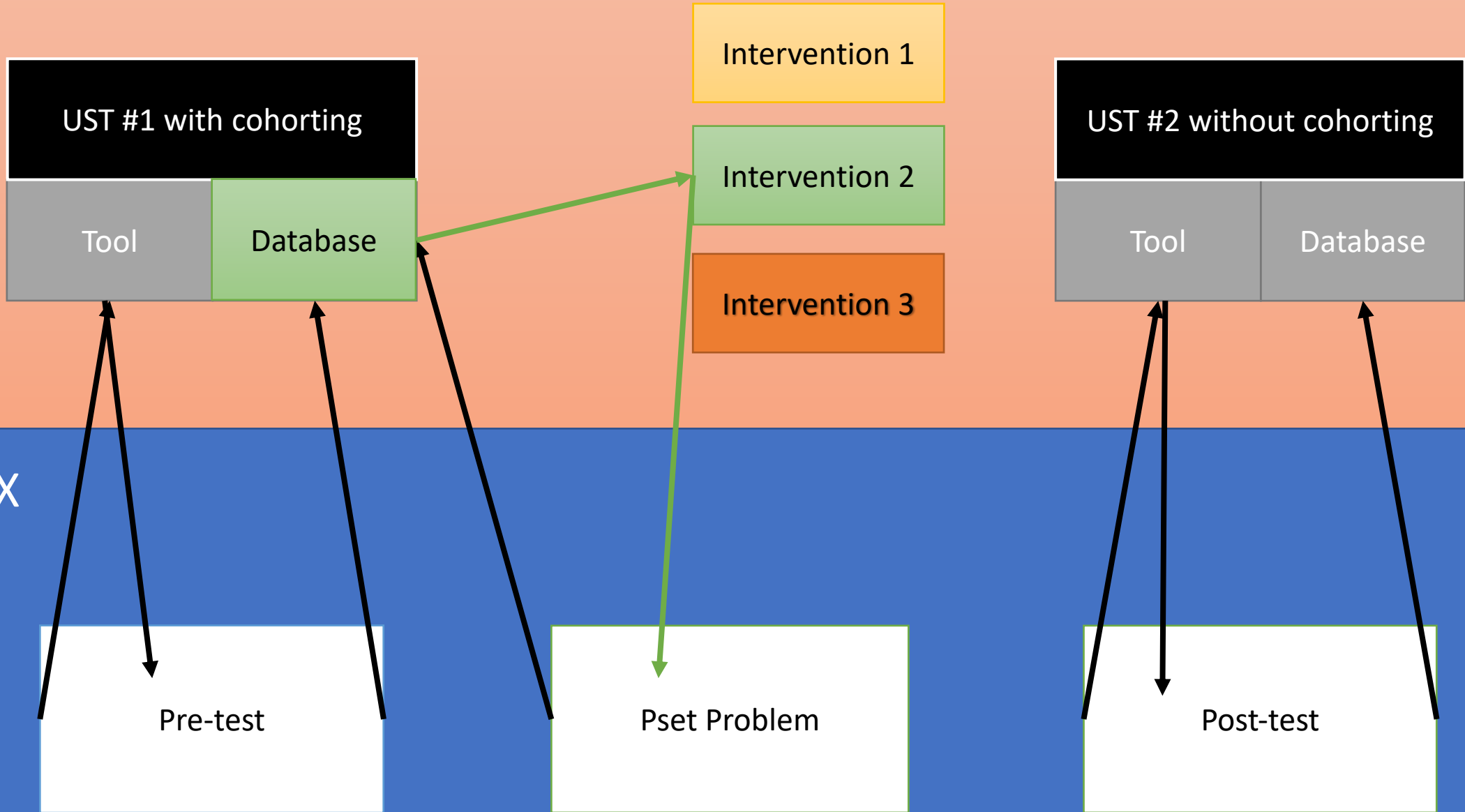
Next Steps

- We plan to run more of these studies as collaboration bandwidth will permits.
- If this study's hypotheses are born out in future studies, such findings may be relevant beyond the realm of undergraduate physics.
 - Chemistry, biology, mathematics, as well as other fields may find that they too can boost subject comprehension by incorporating coding and visualization into their curriculum.
- Share what we have built!

Outcomes

- Demonstration of 2x2 factorial design on MITx with cohort-balancing based on pre-test and personality assessment
- Real time cohorting to balance skills and likelihood of attrition based on standard techniques used in medical and clinical trials where patients enroll on a rolling basis
- Ability to serve differentiated instruction based on learner profiles
- Tools for others to run similar experiments in their online courses!

Wolfram Cloud



Wolfram on edX

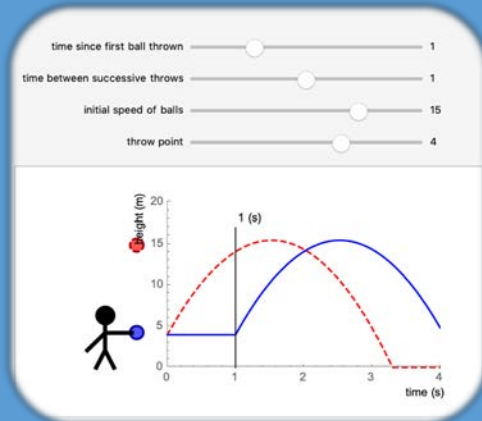
Embed the Following Types of Content
with or without Grading

Forms

What is your answer to
this question?

Submit

iFrame



Coding Notebook

WOLFRAM MATHEMATICA ONLINE Plan: Site (Massachusetts Institute of Technology)

ce8c77acb1d960a2711...

File Format Insert

A notebook to code in!

In[1]= `x = 5 ;`
In[2]= `x ^ 2`
Out[2]= 25

prime factorization | divisors | binary form | number of primes ≤ 25 | more...

Your name as it will appear on this Work Plan.

Kyle Keane

Character limit: 35

Why are you taking this course?

To learn about making my online courses more interactive and computational.

Character limit: 400

Name one person who you will discuss your coursework with:

Andrea Griffin

Character limit: 35

Which days during the week do you plan to work on this course?

Select all that apply.

Sunday Monday Tuesday Wednesday Thursday Friday Saturday

When, approximately, do you plan to do the work?

Select all that apply.

Morning Afternoon Evening

List at least one goal for your first week of work.

Add a widget into my course.

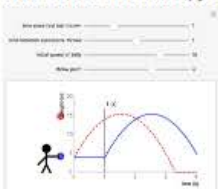
Character limit: 120

Describe goals for your participation over the whole course.

Create the fancy widget I keep telling my friends about.

Character limit: 260

In an earlier submission, you submitted this as a picture that motivates you:



To replace that image with a new one, submit your new motivational image here:

Work Plan

Kyle Keane

To learn about making my online courses more interactive and computational.

I will discuss my course work with Andrea Griffin.

I plan to work on this course:

Sunday **Monday** **Tuesday** **Wednesday** **Thursday** **Friday** Saturday

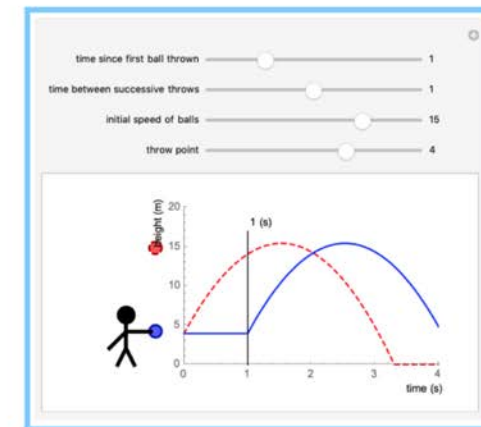
I will typically work: Morning Afternoon **Evening**

Goals for my first week of work:

Add a widget into my course.

Goals for my work over the whole course:

Create the fancy widget I keep telling my friends about.



Step-by-Step Edge Course

View this course as:

[Course](#) [Discussion](#) [Wiki](#) [Progress](#) [Instructor](#)

Wolfram LTI Tools

[Resume Course](#)

[Expand All](#)

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- ▼ [Wolfram in your course](#)
 - [Getting started with Wolfram](#)
 - [What can you do with Wolfram in your course?](#)
- ▼ [Wolfram LTI in your course](#)
 - [Getting Started with Wolfram LTI](#) ✓
 - [Pre-Built Wolfram LTI tools - no coding!](#)
 - [Pre-Built Wolfram LTI tools - requires some coding](#) ✓
- [Making Wolfram LTI Tools From Scratch](#)

Course Tools

[Bookmarks](#)

Important Course Dates

Today is Apr 30, 2019 02:37 EDT

Interactive Deployment Guides

Universal Study Tool

1. Cloud Connect

Connect to the account you will be using to deploy the study

```
In[ ]:= CloudConnect["atg@mit.edu"]
```

```
Out[ ]:= atg@mit.edu
```

2. Evaluate all Helper Functions

3. Edit and Evaluate all initial information

4. Define each section

5. Edit Cohorting information

6. Edit participant selection criteria

7. Evaluate Build Assessment

■ Build Assessment

Run the code below that will set up the assessment and return a LTI URL to insert into the course.

```
In[ ]:= Module[  
  {  
    $dataDirectory = URLBuild[{$cloudDirectory, "data"}],  
    main  
  },
```

(←-----Update all section pages-----→)

Upcoming Trainings

The screenshot shows a web browser window with the URL <https://education.wolfram.com/summer/school/programs/educational-innovation/>. The page features the Wolfram logo and navigation menu. The main content area includes a link to 'Back to Summer Programs', the title 'Wolfram Summer School' with 'FOUNDED IN 2003', and the text '17th Annual Wolfram Summer School, held at Bentley University June 23–July 12, 2019'. A navigation bar highlights 'Programs' and 'EDUCATIONAL INNOVATION' is selected in a sub-menu. The bottom of the page displays 'WOLFRAM EDUCATIONAL INNOVATION TRACK'.

Course | 8.01.1x | edX Educational Innovation paperlesspost.com

WolframAlpha.com | Wo

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[← Back to Summer Programs](#)

Wolfram Summer School

 FOUNDED IN 2003

17th Annual Wolfram Summer School, held at Bentley University
June 23–July 12, 2019

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SCIENCE TECHNOLOGY & INNOVATION EDUCATIONAL INNOVATION

WOLFRAM EDUCATIONAL INNOVATION TRACK

MITx

SIGNIFICANT INTEREST GROUP EVENT

FRIDAY, MAY 17, 2019

11:30AM - 1:30PM

SAMBERG CONFERENCE CENTER (E52)

The MITx SIG Event provides an opportunity for MIT faculty, staff, and fellows to come together to discuss innovations, lessons learned, and best practices across both residential and global digital learning. Please join us for lunch and presentations from your colleagues. We will also award the MITx Prize for Teaching & Learning in MOOCs.

A full agenda will be shared shortly.

Please RSVP by May 6th.

Please note that this event is by invite only. If you would like to bring a guest, please contact mitxonedX@mit.edu.