CS 357 – Numerical Methods 1

We will **not** use the Zoom chat for questions

Instead, all questions should be posted on **Discord**

Course staff will be answering questions in real-time during class

Join Discord

Meeting Mariana

Teaching Associate Professor

https://mfsilva.web.illinois.edu

mfsilva@illinois.edu

Research Area: Computers and Education

- Started teaching at UIUC Sp 2012
- Taught 10 different courses
- Teaching CS 357 since Sp 2018
- Co-teaching CS 500 and CS 101 this semester

My research interests

- Fostering collaborations and group work in the classroom
- Adoption of technological innovations for large-scale teaching
- Computer-based testing
  - Reducing anxiety
  - Reducing cheating

- My most recent professional endeavors
  - Co-founded PrairieLearn Inc in 2021

Meet Course Staff

Get support

- All communication will happen via Discord. NO EMAILS!
- Check Discord often (specially the #announcement channel)
- Office Hours: in-person and virtual options (**starts on week 2**)
- Happy Hours: Siebel 2213 Tuesdays 3-4pm (**starts on week 2**)

Other important announcements

- Eating is NOT allowed in classroom. You must eat your lunch after class.
- Course Survey and Consent Form

Course Website - Syllabus

https://courses.engr.illinois.edu/cs357/pages/syllabus.html

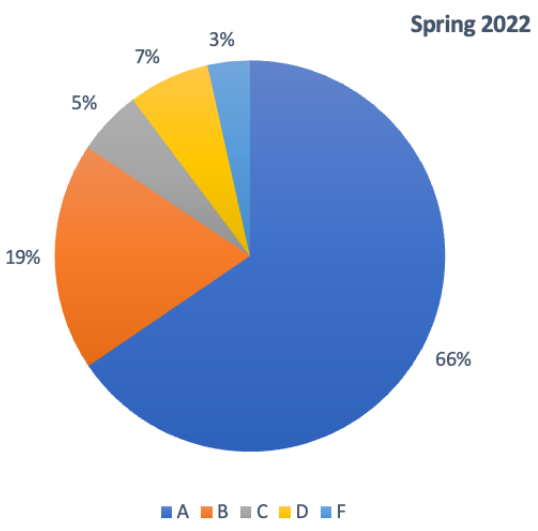
Course Assessments

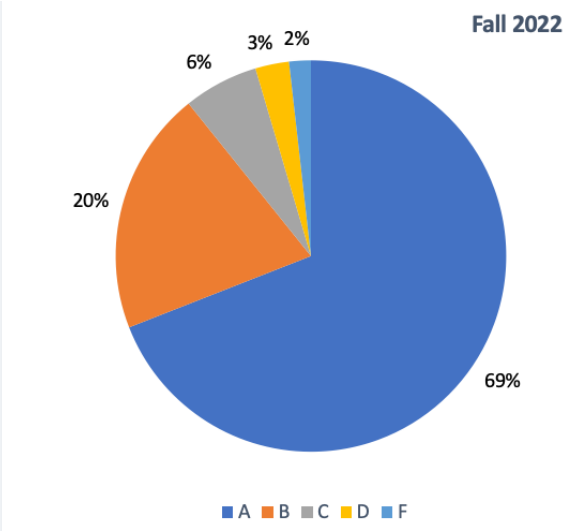
Assessment	Contribution	Info
Final exam	15%	Delivered via PrairieLearn at the CBTF (asynchronously with self-registration).
Bi-weekly quizzes	35%	Delivered via PrairieLearn at the CBTF (asynchronously with self-registration). Read more here.
Homework	25%	Submitted twice weekly via PrairieLearn.
MP	10%	Submitted 5 times during the semester via PrairieLearn.
Group Activity	11%	Weekly group work to be completed on Tuesdays (read more here).
Pre-Lecture Activity	4%	Pre-recorded videos available via PrairieLearn on Tuesdays and Thursdays with corresponding short questions

Final Letter Grade Calculation

Grade	Point Range
A	[93, 100)
A-	[90, 93)
B+	[87, 90)
B	[83, 87)
B-	[80, 83)
C+	[77, 80)
C	[73, 77)
C-	[70, 73)
D+	[67, 70)
D	[63, 67)
D-	[60, 63)
F	< 60

- We never curve
- We do not round grades
- Up to 1% in extra credit points
- A+ given to top 5% students





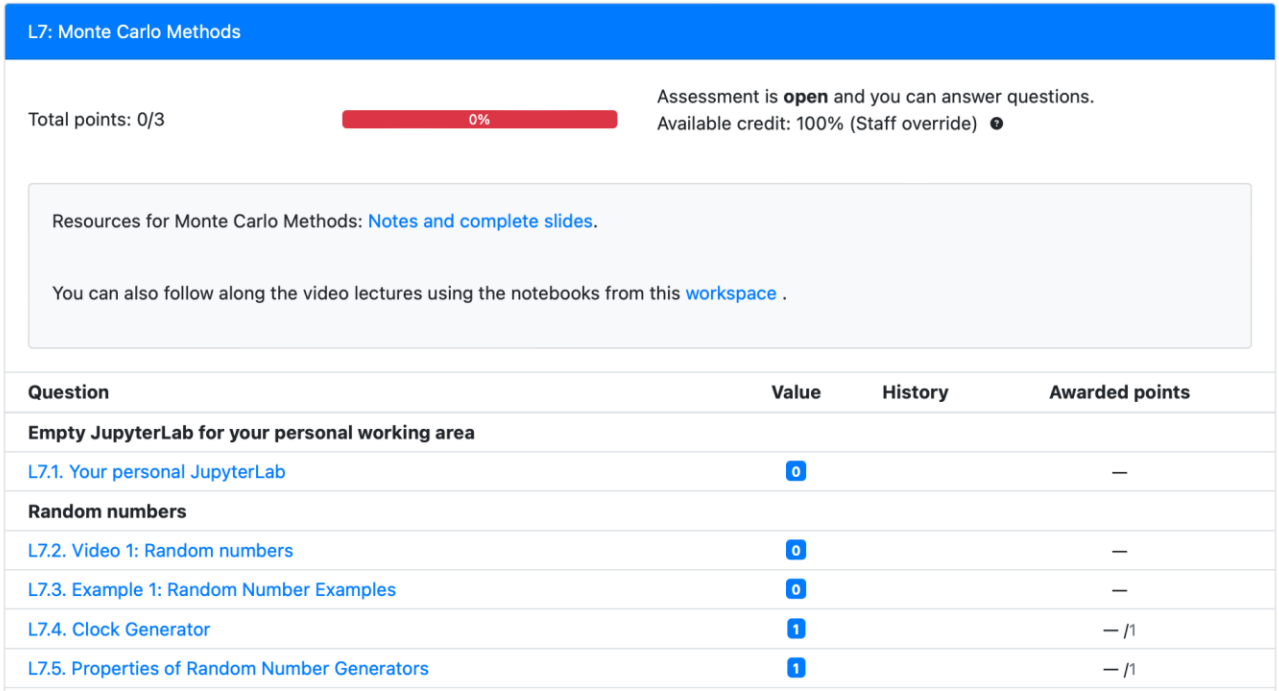
Assessments (all in PrairieLearn)

Module 7. Randomness and Monte Carlo Methods	
L7	Monte Carlo Methods
HW7	Monte Carlo Methods
D7	Demo: Random numbers and Monte Carlo methods
GA 4	Using random walk to model stock market
MP 1	Machine Problem 1: Numerical Experiments using Monte Carlo

- (Pre-)Lecture
- Demo
- Group Activity
- Homework
- Machine Problem
- Practice Quiz

Let us know if you are not familiar with PrairieLearn and/or PrairieTest. We can give you a demo during office hours.

Pre-Lectures



L7: Monte Carlo Methods

Total points: 0/3 — 0%

Assessment is **open** and you can answer questions.
Available credit: 100% (Staff override)

Resources for Monte Carlo Methods: Notes and complete slides.

You can also follow along the video lectures using the notebooks from this workspace .

Question	Value	History	Awarded points
Empty JupyterLab for your personal working area			
L7.1. Your personal JupyterLab	0		–
Random numbers			
L7.2. Video 1: Random numbers	0		–
L7.3. Example 1: Random Number Examples	0		–
L7.4. Clock Generator	1		– /1
L7.5. Properties of Random Number Generators	1		– /1

- Videos + short check-point questions
- Option to read online textbook and/or slides
- 4 lowest scores will be dropped (4% of final grade)

Homework

HW7: Monte Carlo Methods

Total points: 0/24 — 0%

Assessment is **open** and you can answer questions.
Available credit: 100% (Staff override)

Question	Value	History	Awarded points
Empty JupyterLab for your personal working area			
HW7.1. Your personal JupyterLab	0		—
Linear Congruential Generators			
HW7.2. Linear Congruential Generators	1		— /3
Monte Carlo Conceptual			
HW7.3. Where to use Monte Carlo	1		— /1
HW7.4. Monte Carlo Convergence Definition	1		— /1

- 6-15 questions (MC, checkbox, fill-in-the-blank, coding)
- 2 lowest scores will be dropped (25% of final grade)

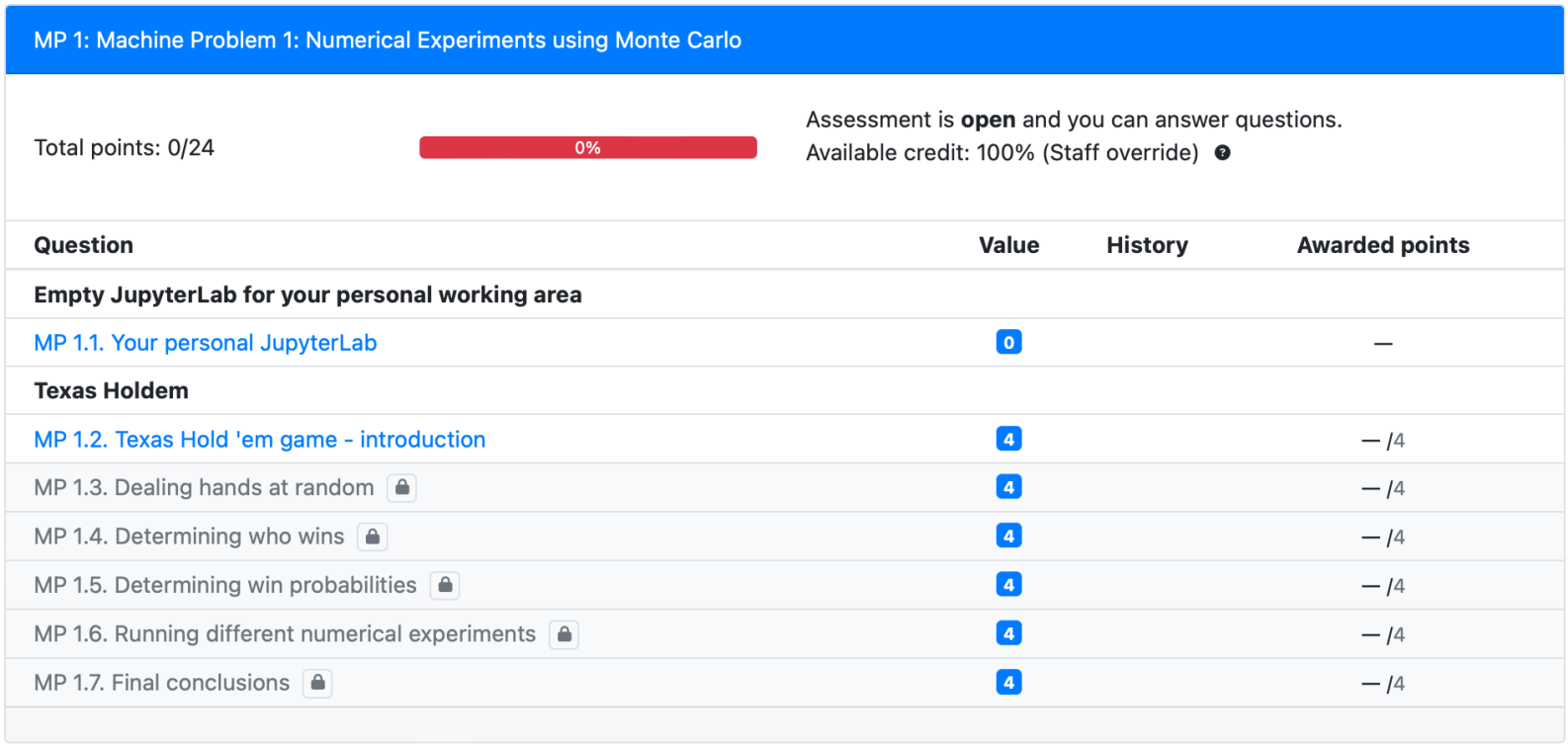
Group Activity (Tuesdays)

- Completed on Tuesdays, open from 11am - 10pm
- Required class attendance for students in Section N (but can still complete the GA until 10pm)
- Section M students can complete the GA anytime on Tuesday, from any location. However support is only provided during class time via Discord.
- Mini-introduction (5-10 min): section M students can join on Zoom
- lowest score will be dropped (11% of final grade)
- More about GAs next class

Study Hall (Thursdays)

- Optional attendance
- More examples and review
- Canceled 6 times during the semester (to compensate for quiz scheduling)

Machine Problems



MP 1: Machine Problem 1: Numerical Experiments using Monte Carlo

Total points: 0/24 — 0%

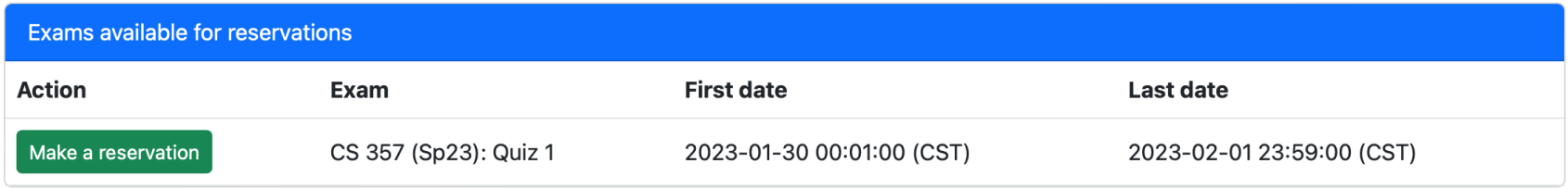
Assessment is **open** and you can answer questions.
Available credit: 100% (Staff override)

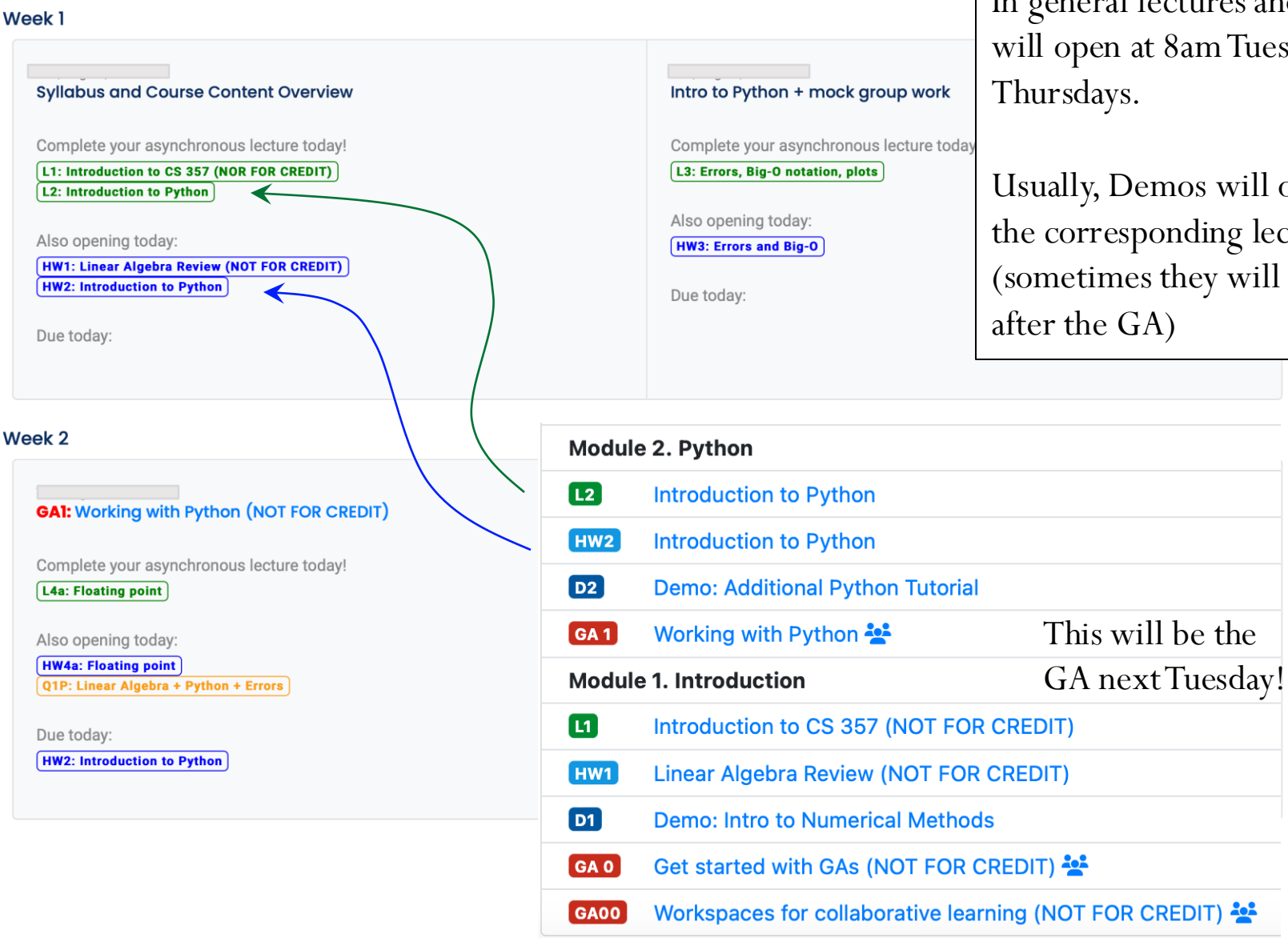
Question	Value	History	Awarded points
Empty JupyterLab for your personal working area			
MP 1.1. Your personal JupyterLab	0		—
Texas Holdem			
MP 1.2. Texas Hold 'em game - introduction	4		— /4
MP 1.3. Dealing hands at random	4		— /4
MP 1.4. Determining who wins	4		— /4
MP 1.5. Determining win probabilities	4		— /4
MP 1.6. Running different numerical experiments	4		— /4
MP 1.7. Final conclusions	4		— /4

- Longer coding problems
- Scaffolded
- Appear 5 times in the semester, no drops (10% of final grade)

Quizzes

- 6 quizzes; lowest score is dropped (35% of final grade)
- 8-12 non-coding questions + 2-3 coding questions
- 50-min quizzes all at CBTF (check schedule on course website)
- DRES students should provide letter to CBTF
- We will use PrairieTest to make quiz reservations.
- MAKE YOUR RESERVATION AS SOON AS SLOTS OPEN! We will not provide special overrides because you were not able to find a slot that works for you.
- Practice Quizzes – generated mostly from the same set of questions that will generate the actual quizzes



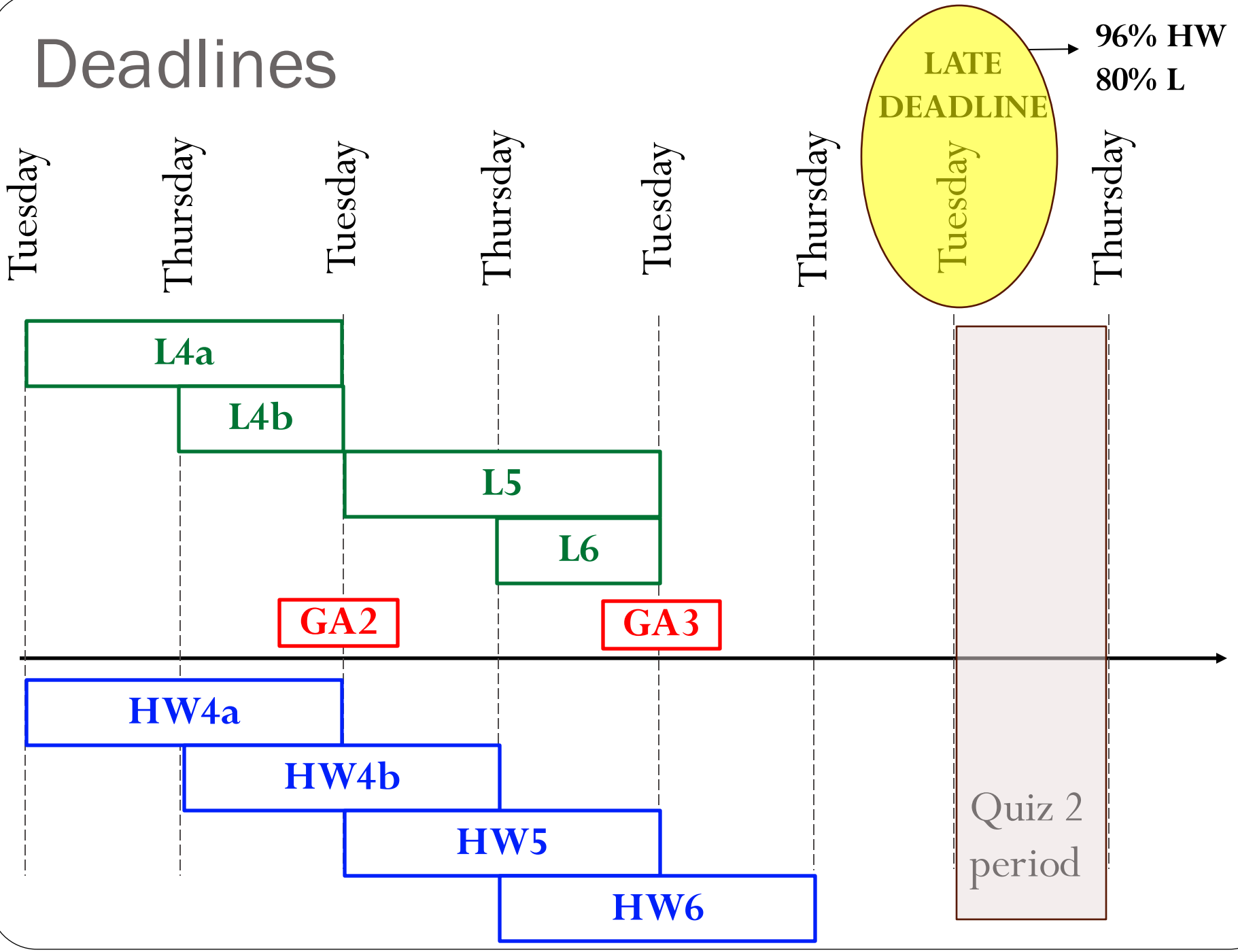


In general lectures and HWs will open at 8am Tuesdays and Thursdays.

Usually, Demos will open with the corresponding lectures (sometimes they will appear after the GA)

This will be the GA next Tuesday!

Deadlines


LATE DEADLINE
Tuesday
96% HW
80% L
Tuesday
Thursday
Tuesday
Thursday
Tuesday
Thursday
Thursday
L4a
L4b
L5
L6
GA2
GA3
HW4a
HW4b
HW5
HW6
Quiz 2 period

Learning Flow for each Module

1. Complete lectures on Tuesdays and Thursdays as they open
    - Get up to 100% credit by completing them before Tuesday 12pm of the week after they open
    - Get up to 80% credit by completing them before Tuesday midnight of the corresponding quiz week
    - Get up to 50% credit by completing them before last day of classes
2. Complete the Homework
    - Get up to 100% credit by completing them within one week after they open
    - Get up to 96% credit by completing them before Tuesday midnight of the corresponding quiz week
    - Get up to 50% credit by completing them before last day of classes
3. Complete MPs (when available) – similar deadline scheme as HW
4. For additional examples, look at the Demos (not for credit)

Practice Quizzes

1. You are encouraged to start the practice quizzes only after you complete the learning flow above
2. Complete at least one entire practice quiz as if you were taking the quiz (no access to resources, timed, etc). This will give you a good idea of how ready you are.

Quiz 1: Modules 1-3

PQ1 Practice Quiz 1: Linear Algebra + Python + Errors (NOT FOR CREDIT)

Q1 Quiz 1: Linear Algebra + Python + Errors

Module 3. Errors and Big-O

L3 Errors, Big-O notation, plots

HW3 Errors and Big-O

D3 Demo: Errors

Module 2. Python

L2 Introduction to Python

HW2 Introduction to Python

D2 Demo: Additional Python Tutorial

GA 1 Working with Python (NOT FOR CREDIT)

Module 1. Introduction

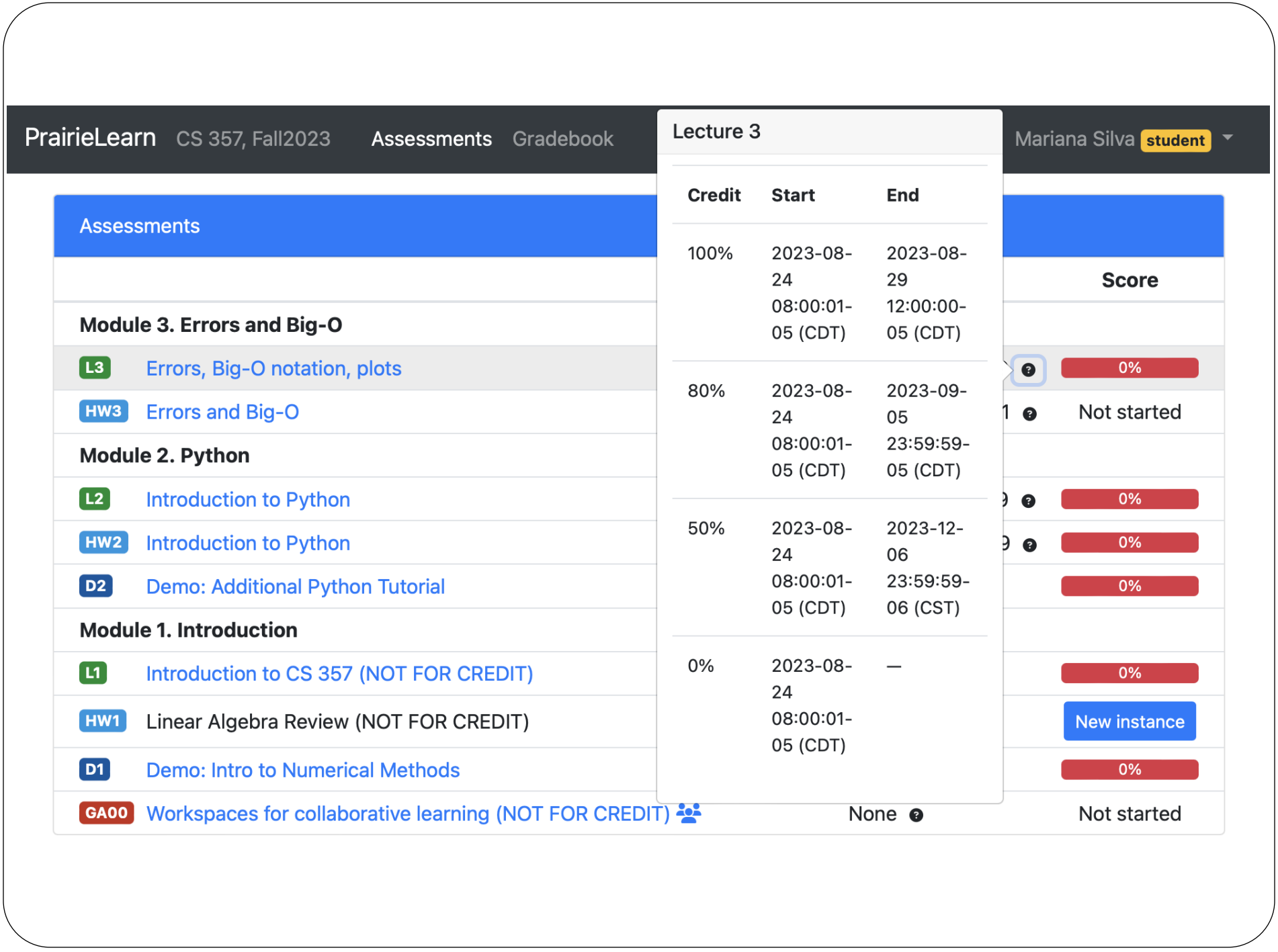
L1 Introduction to CS 357 (NOT FOR CREDIT)

HW1 Linear Algebra Review (NOT FOR CREDIT)

D1 Demo: Intro to Numerical Methods

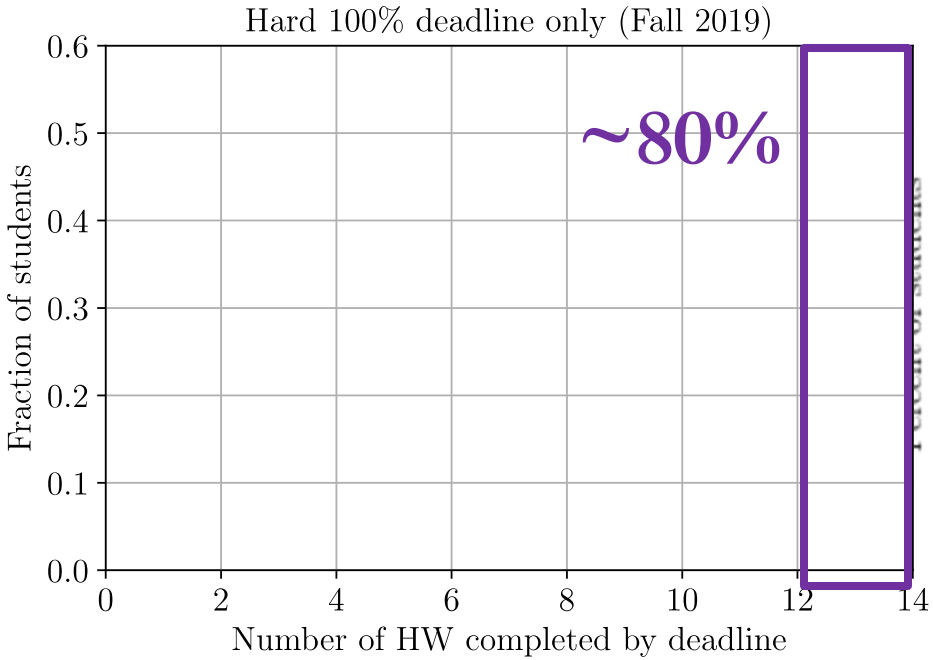
GA 0 Get started with GAs (NOT FOR CREDIT)

GA00 Workspaces for collaborative learning (NOT FOR CREDIT)

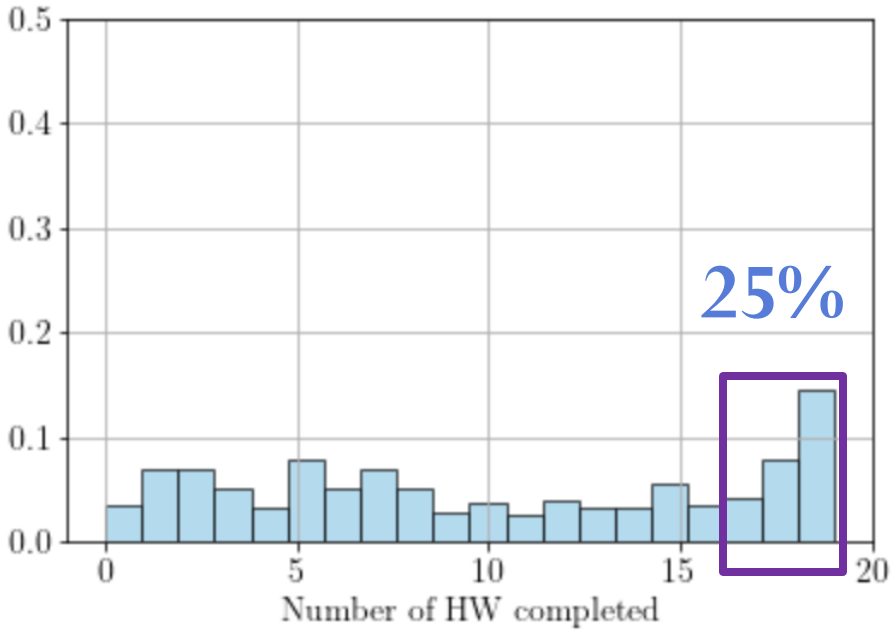

PrairieLearn
CS 357, Fall2023
Assessments
Gradebook
Mariana Silva student
Assessments
Score
Module 3. Errors and Big-O
L3 Errors, Big-O notation, plots
0%
HW3 Errors and Big-O
Not started
Module 2. Python
L2 Introduction to Python
0%
HW2 Introduction to Python
0%
D2 Demo: Additional Python Tutorial
0%
Module 1. Introduction
L1 Introduction to CS 357 (NOT FOR CREDIT)
0%
HW1 Linear Algebra Review (NOT FOR CREDIT)
New instance
D1 Demo: Intro to Numerical Methods
0%
GA00 Workspaces for collaborative learning (NOT FOR CREDIT)
None
Not started
Lecture 3
Credit
Start
End
100%
2023-08-24 08:00:01-05 (CDT)
2023-08-29 12:00:00-05 (CDT)
80%
2023-08-24 08:00:01-05 (CDT)
2023-09-05 23:59:59-05 (CDT)
50%
2023-08-24 08:00:01-05 (CDT)
2023-12-06 23:59:59-06 (CST)
0%
2023-08-24 08:00:01-05 (CDT)
—

What did we learn about flexible deadlines in this class?

With "hard" one-week deadlines



With flexible deadlines

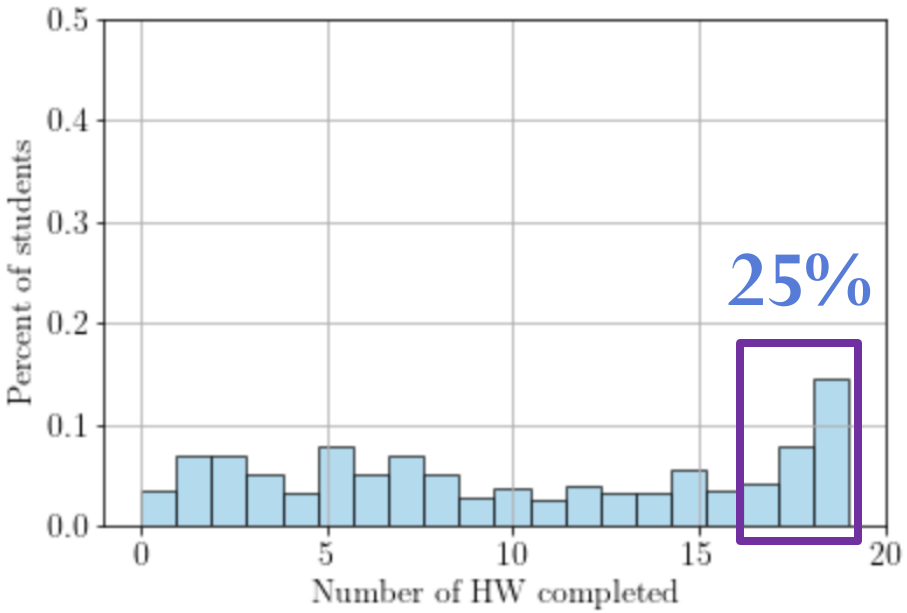


Percent of students who complete most of the HW decreased from ~80% to ~25%!

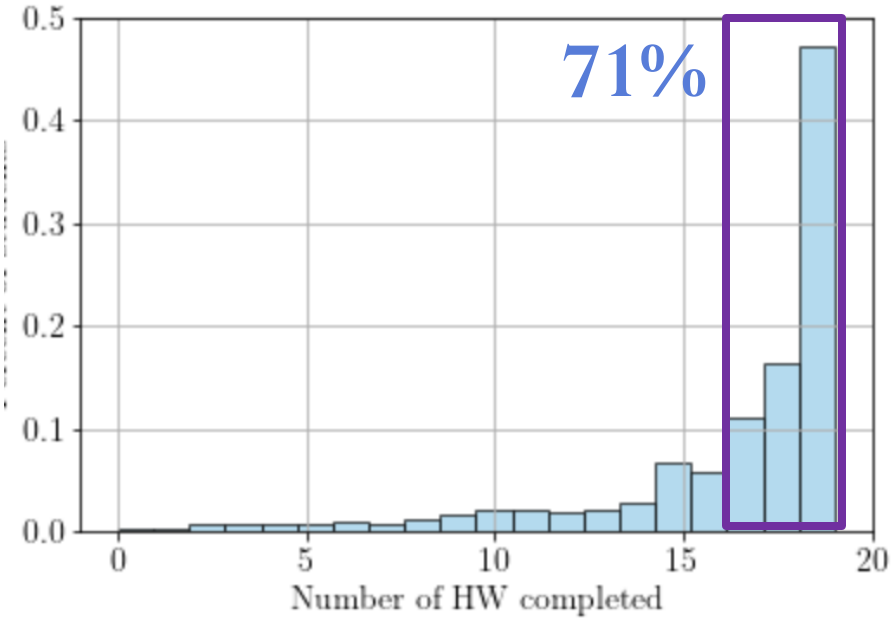
What did we learn about flexible deadlines in this class?

With flexible deadlines

Completion by 100% deadline



Completion by 96% deadline

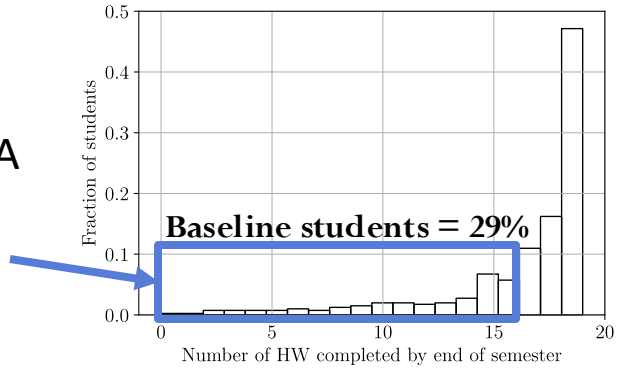


Percent of students who complete most of the HW
Increased to 71% by the quiz date

How HW completion impact quiz performance

Regression model to fit exam scores including control for GPA

Baseline: students who did not complete HWs by the exam date



Students who complete HWs …	average score advantage on exams	% students
Do not complete	0% (baseline)	29%
by exam date	14.4%	46%
within one week	18.6%	25%

WEEKS 1-2:

Both Tuesday and Thursday:

- Synchronous hybrid class for all students
- Section N at CIF
- Section M join on Zoom

STARTING FROM WEEK 3:

Tuesdays:

- Group activity
- Attendance required only for students in section N
- Section M students support via Discord
- Zoom for **mini-lecture** only

Thursday:

- **Optional** Study Hours
- Additional examples
- All students who want to get this additional help should go to CIF
- **No Zoom option**

Difference between Sections M and N

Section N (in-person)	**Section M (online)**
Attendance is required	Attendance not required
Start GA during class time. Most groups will complete GA before the end of the class. Can still complete GA until 10pm	Can start GA at any time from 11am and complete by 10pm.
Support during class time at CIF 35. We will have 7 course staff at CIF.	Support during class time via Discord. We will have 8 course staff on Discord duty. Some will be assigned to reply to text messages and some will join the voice channel.
A student can request remote attendance in case of sickness. The remote arrangements should be decided by the group. Remote attendance will be verified by course staff during class time.	Students can make arrangements for remote attendance when someone is sick without communication with course staff (in case a group meets in-person)

How the final GA score is computed

Section N (in-person)

Attendance = 0 or 1 (1 if attended class)

GAi-Grade (Canvas) = GAi-PL-Grade * Attendance

(all GAs i=2,13 are computed using this rule)

Section M (in-person)

GAi-Grade (Canvas) = GAi-PL-Grade

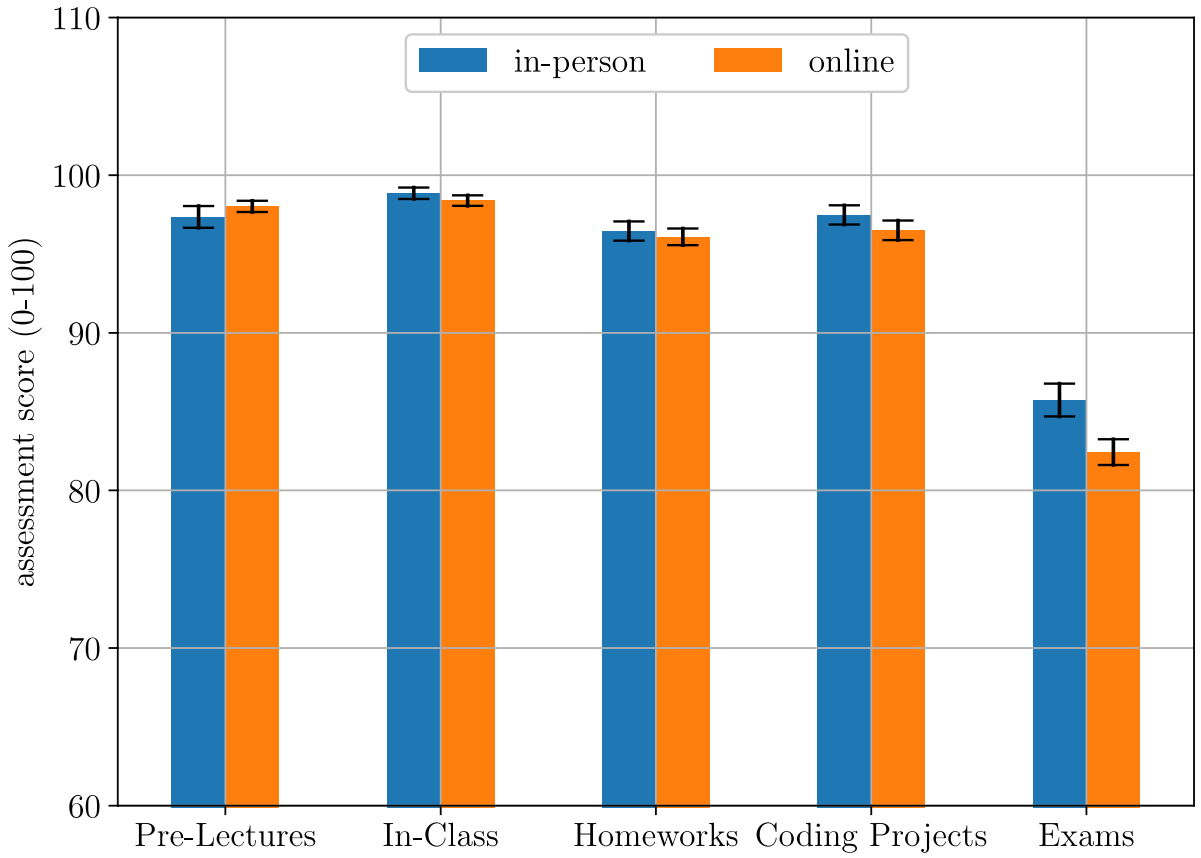
(i = 2,12 except for i=7)

PeerSurvey1 and PeerSurvey2 = 0 or 1 (1 if completed)

GA7-Grade (Canvas) = GA7-PL-Grade * PeerSurvey1

GA13-Grade (Canvas) = GA13-PL-Grade * PeerSurvey2

What do we know about online vs in-person sections in CS 357?



In-person and Online students have similar performance on all "learning" assignments

In-person students have ON AVERAGE a small (2.4%) score advantage on quizzes when compared to **online** students

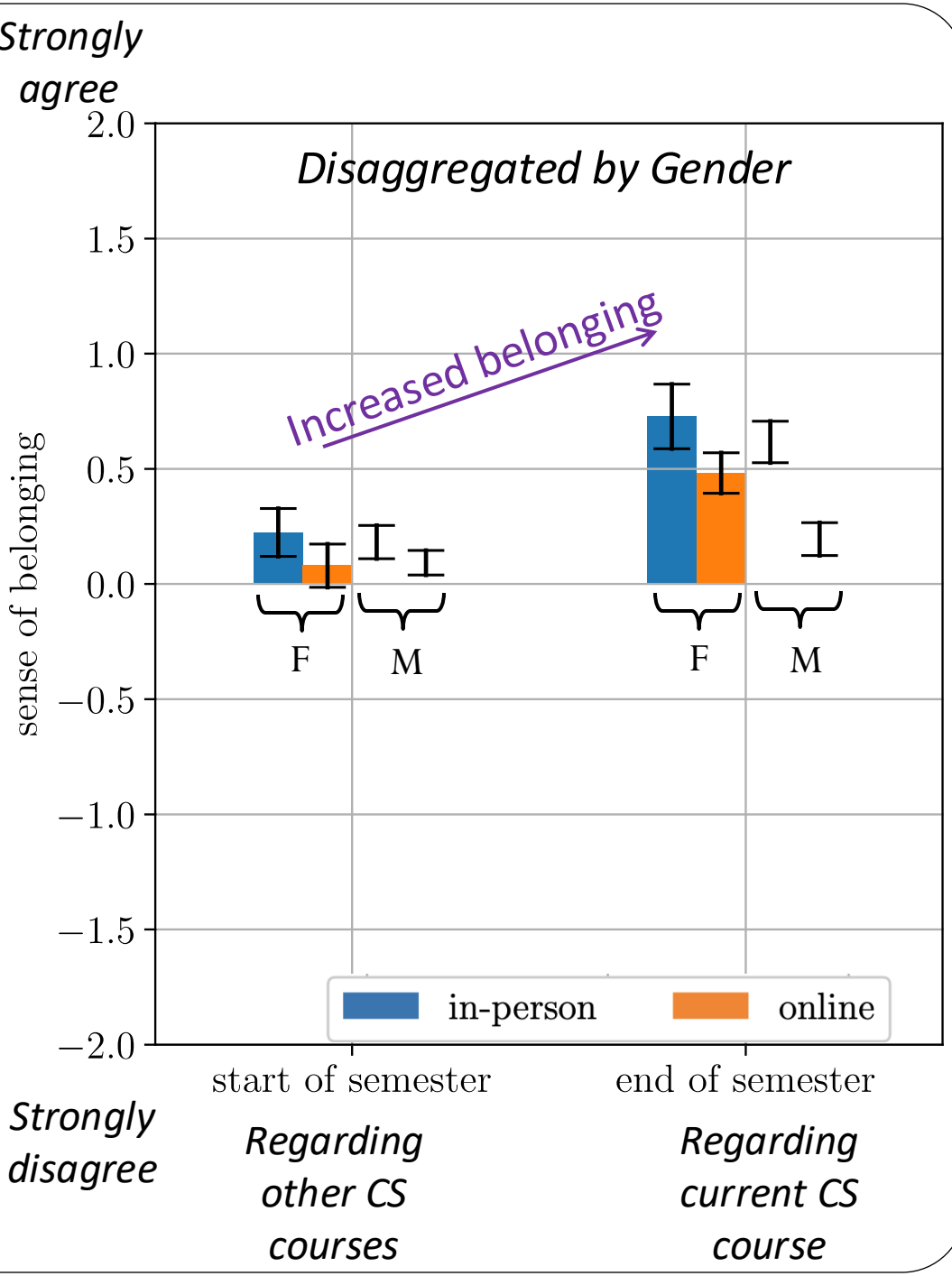
Sense of Belonging

Survey questions regarding perceived comfort, support, and isolation

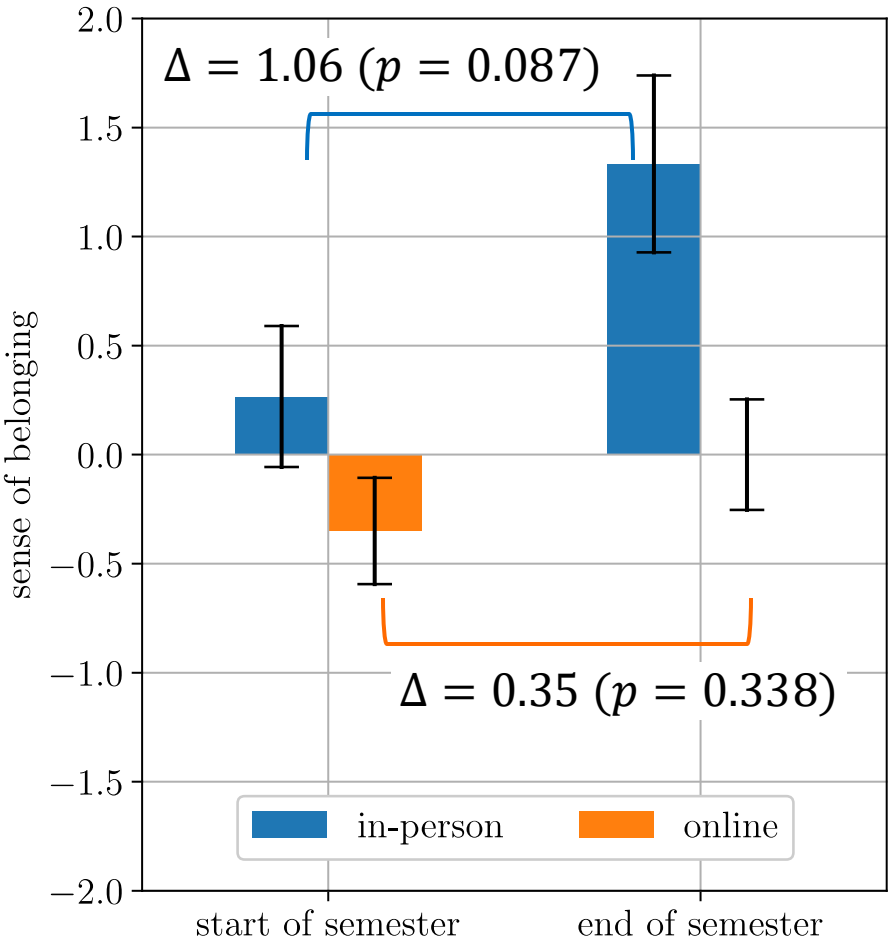
Increased SoB over the semester

In-person students report **higher increase in SoB** when compared to **online** students

Online section: not significant increase in SoB for men; significant increase in SoB for women



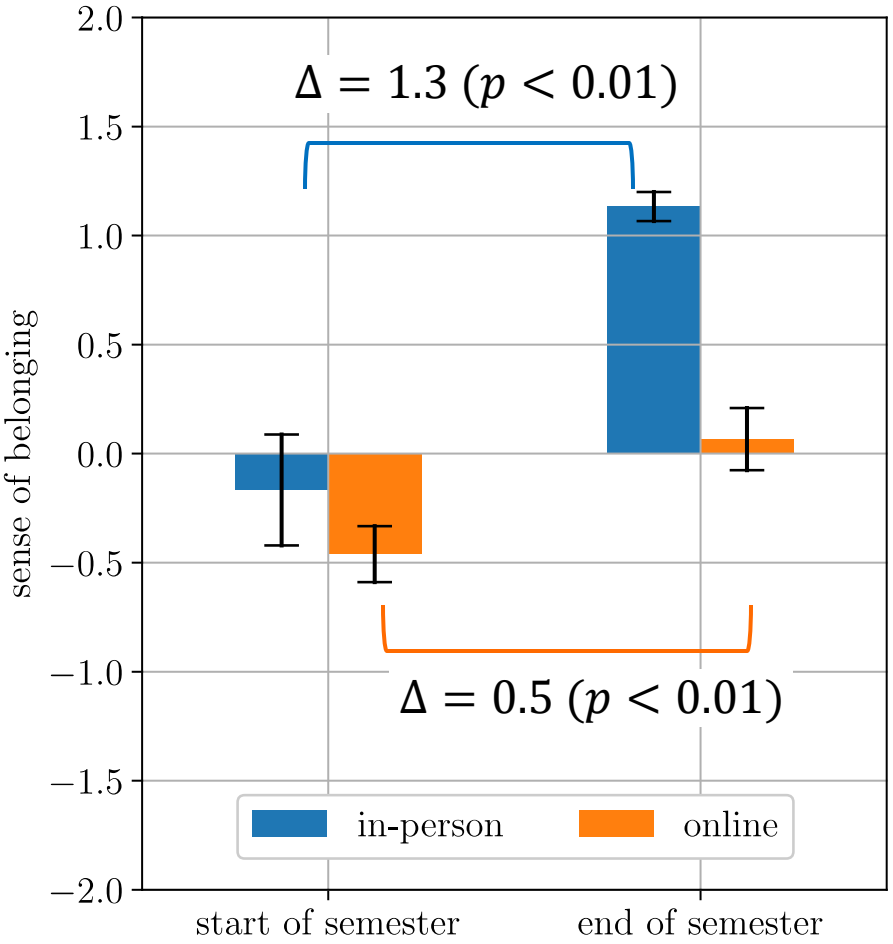
URM only



Regarding other CS courses

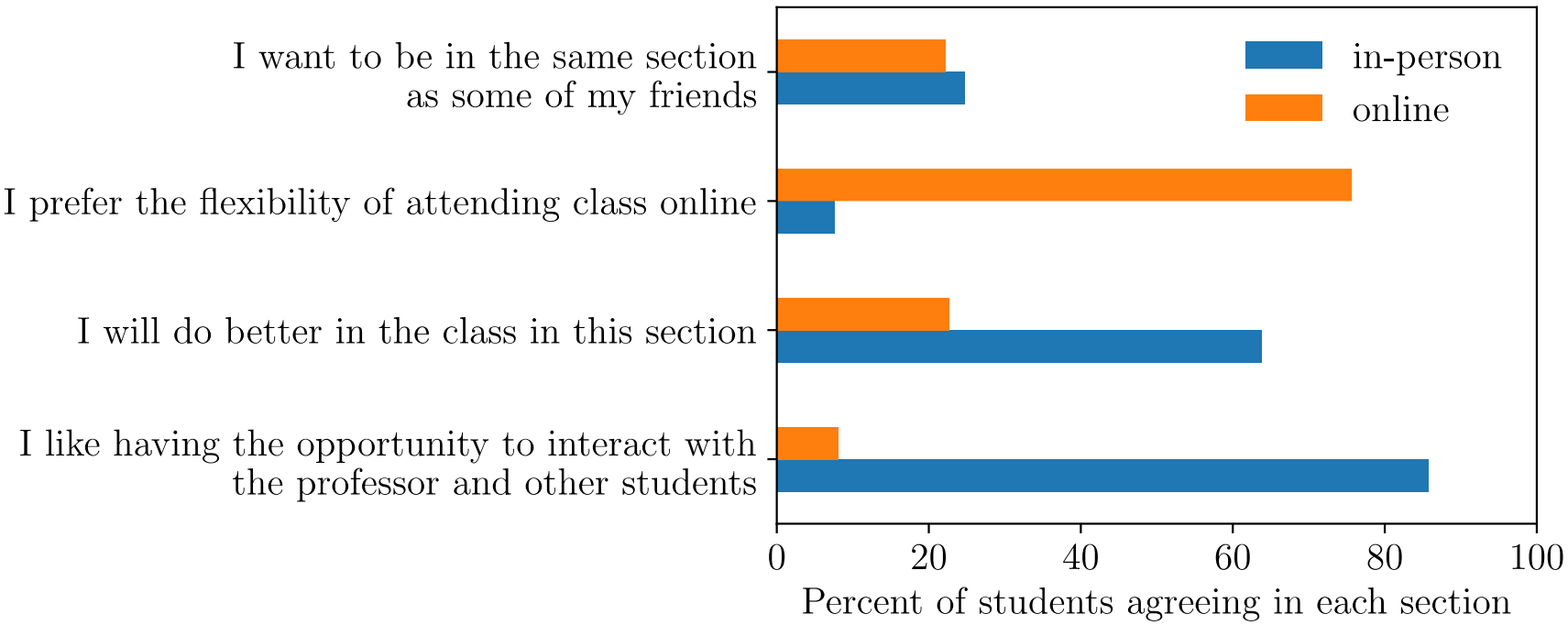
Regarding current CS course

First-Generation only



Regarding other CS courses

Regarding current CS course



Students select the section that best fit their preferences

Introduction and “Big Idea”

What are…

Numerical Methods ?

Numbers in a computer
(and how computer understands these numbers)

- Mathematical model
  - "algorithms" derived from math ideas to solve equations numerically
- Complexity of the problem
  - Slow vs fast
- Accuracy
  - Accurate vs inaccurate

Method = Math + Complexity + Accuracy

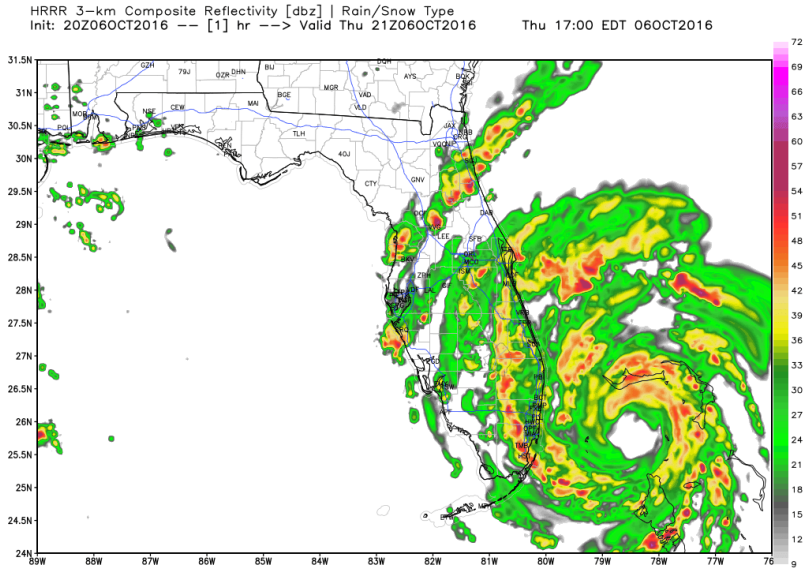
Why is this course important?

1. Understanding and reconstruction of known problems
   - Natural disasters
   - Catastrophic failures

2. Prediction of unknown situations
   - Weather conditions
   - Behavior of new materials

3. Optimization of existing problems
   - Image recognition
   - Reduce fabrication costs

Explosion of Ariane 5 in 1996



Goals for this course

- Understand how numbers are represented in the computer.
- When developing code, you will likely run into numerical errors. What are the sources of these errors?
- How can you avoid numerical errors?
- How can you choose a suitable algorithm for a given application?
- Use existing libraries to solve real applications.

(Numerical) **Method** = **Math** + Complexity + Accuracy

Mathematical model:

What equations can we use to represent our problem?

Accuracy:

Are we getting accurate results?
Why is the method not giving me the correct solution?

Complexity:

How long does it take to solve this problem?
Is it cost-effective?

Your entire CS 357 semester in a few slides!

Are you ready?

Accuracy

- Why a numerical method might not give the right answer?

  - Computers have finite representation of numbers
  - Sometimes the "right answer" cannot be represented in a finite way
  - Example:

$$\pi = 3.14159265358979323846264338327950288419 71\ldots$$

Demo: Waiting for the number 1

```
from time import sleep

x = 0.0

while x != 1.0:
    x += 0.1
    print(repr(x))

    sleep(0.1)
```

What is going to happen when we run this code?

A. Code will stop after printing 11 values for x
B. Code will stop after printing 10 values for x
C. Code will not stop
D. Code will not start

Monte Carlo Methods

Texas Holdem Game: we would like to determine the probability of winning of a given starting hand

Physical experiment

vs

Numerical experiment

Numerical Experiments

- What do we want to know about a numerical experiment?
  1. What questions are we attempting to answer?
  2. What is the outcome of the experiment?
  3. Is it repeatable?
  4. Is the answer accurate?
  5. How long will it take?

Time vs accuracy trade-off

Question: Is running this method (with a certain accuracy) a good use of our time and/or computer resources?

Complexity

How long does it take to solve a problem?

Given A, B matrices of size $m \times m$, the matrix-matrix multiplication $A \cdot B$ takes τ seconds.

How long does it take to perform $C \cdot D$, matrices of size $2m \times 2m$?

```
from time import process_time
import numpy as np
from time import process_time
```

```
n = 2000
A = np.random.randn(n,n)
B = np.random.randn(n,n)

t = process_time()  # store the time
C = A @ B
t = process_time() - t
print(t)
```

```
A = np.random.randn(2*n,2*n)
B = np.random.randn(2*n,2*n)

t2 = process_time()  # store the time
C = A @ B
t2 = process_time() - t2
print(t2)
```

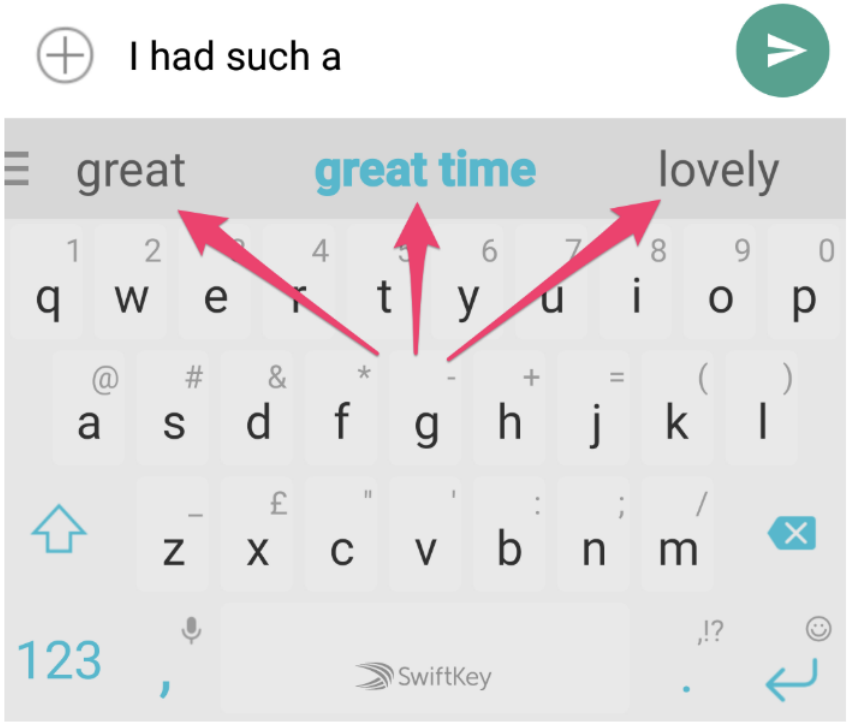
Linear system of equations: Image processing

How can we use linear operators to create blurred images? How can we do the inverse process?

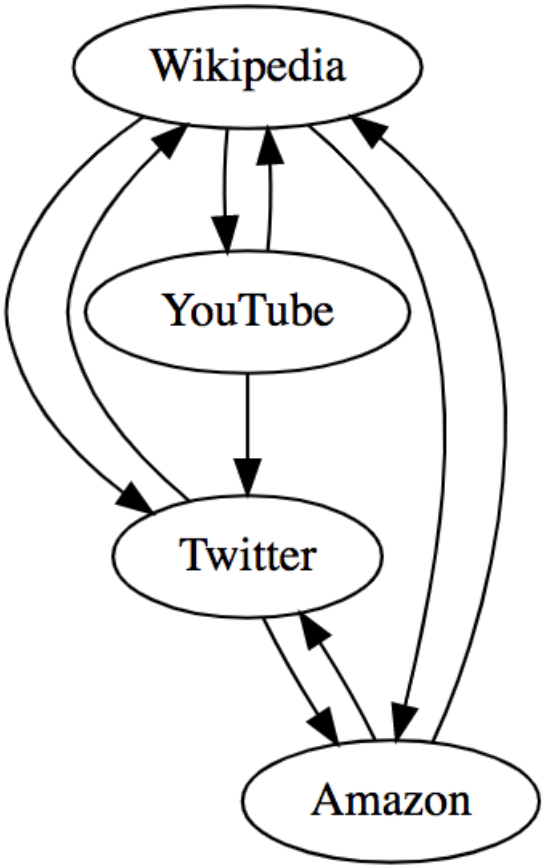
Image credit: https://datacarpentry.org/image-processing/

Markov chain

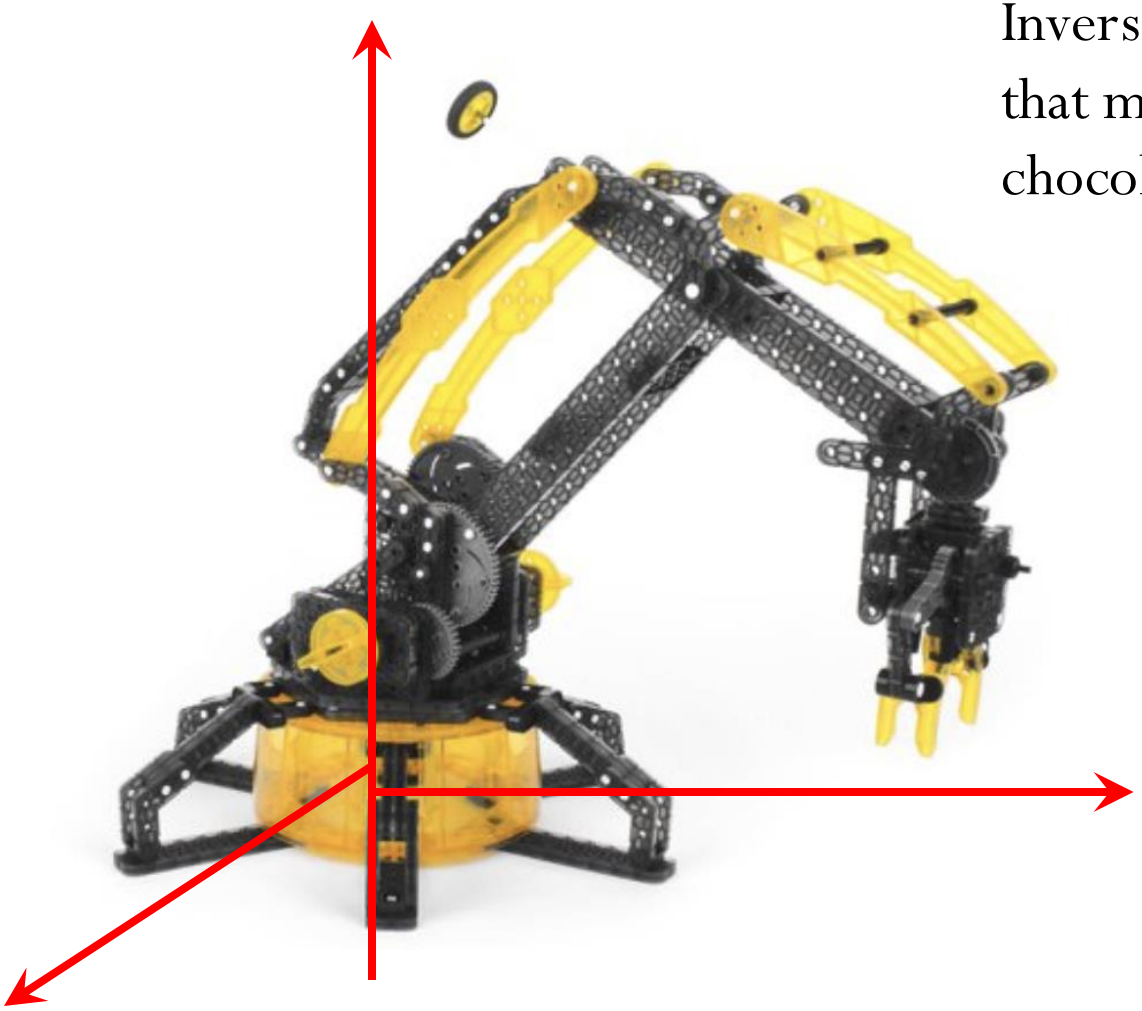
Word prediction



Page Rank



Nonlinear system of equations

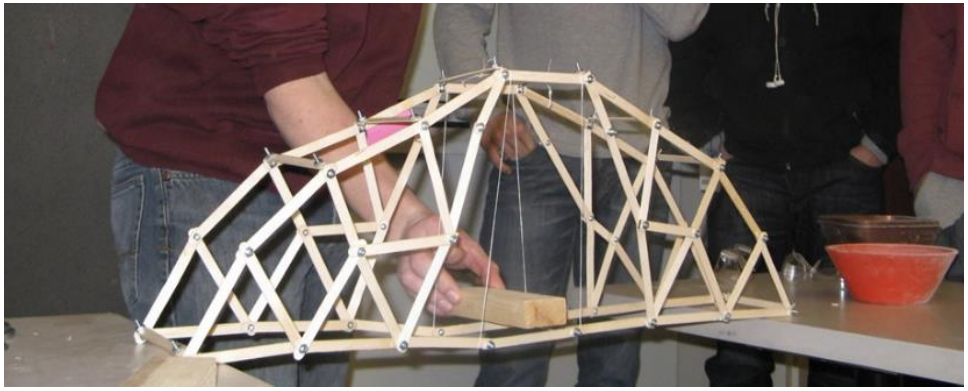


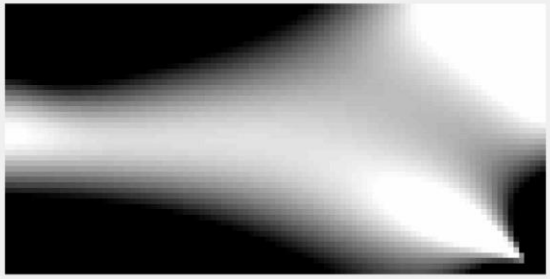
Inverse kinematics: find the angles that make the robotic hand grab a chocolate candy!

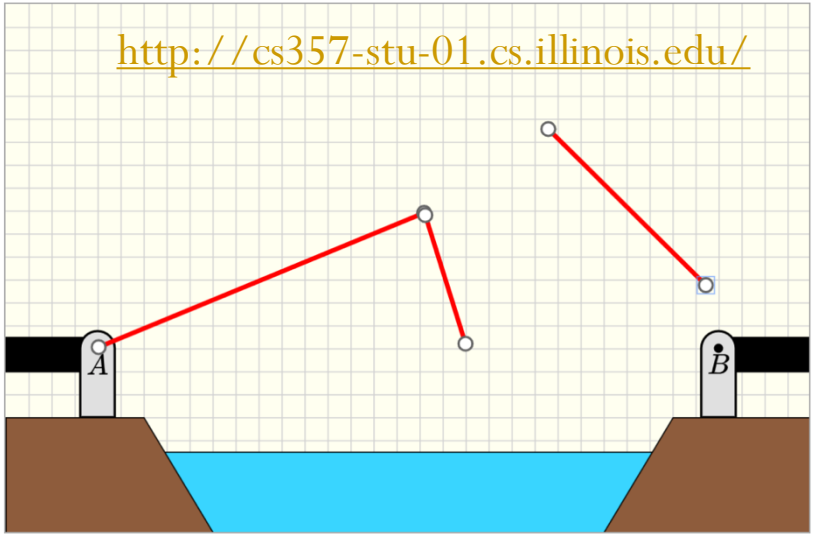
Optimization

Numerical simulations to find optimized bridge designs

Bridge design (high school projects)

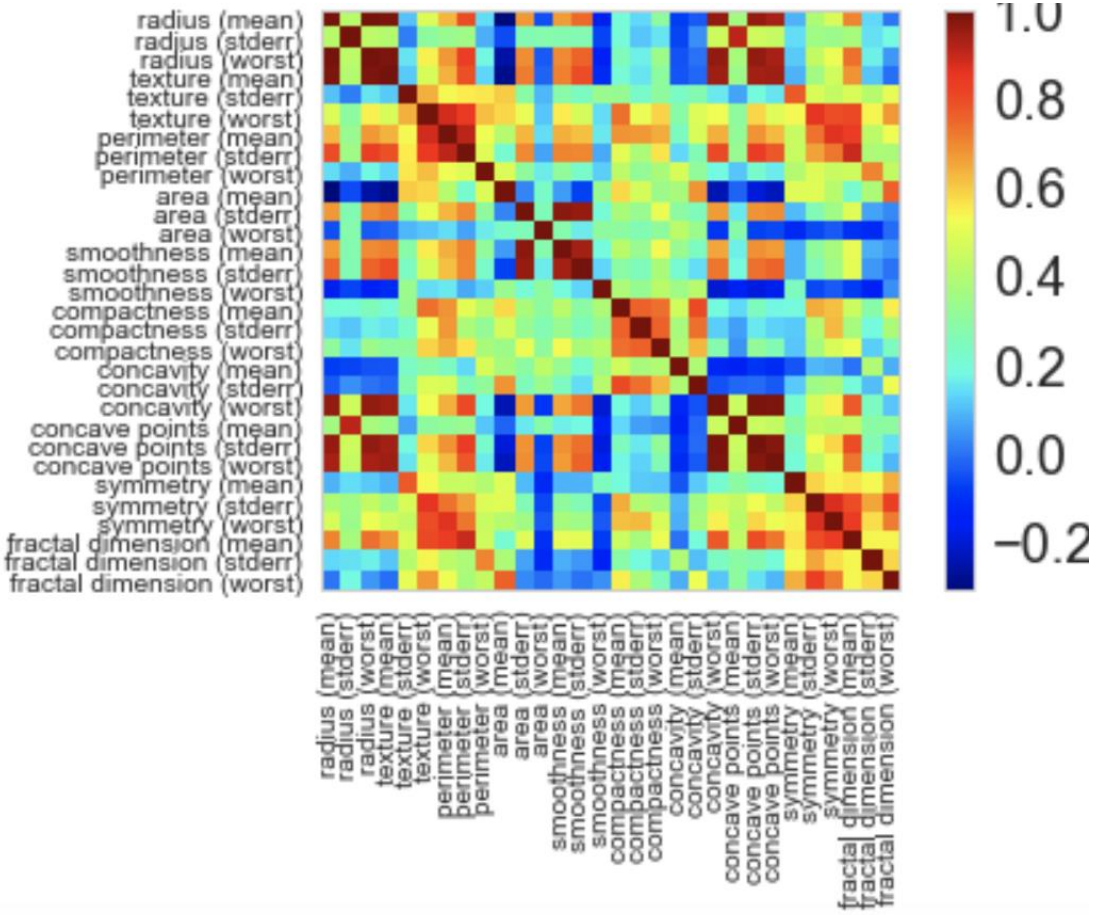


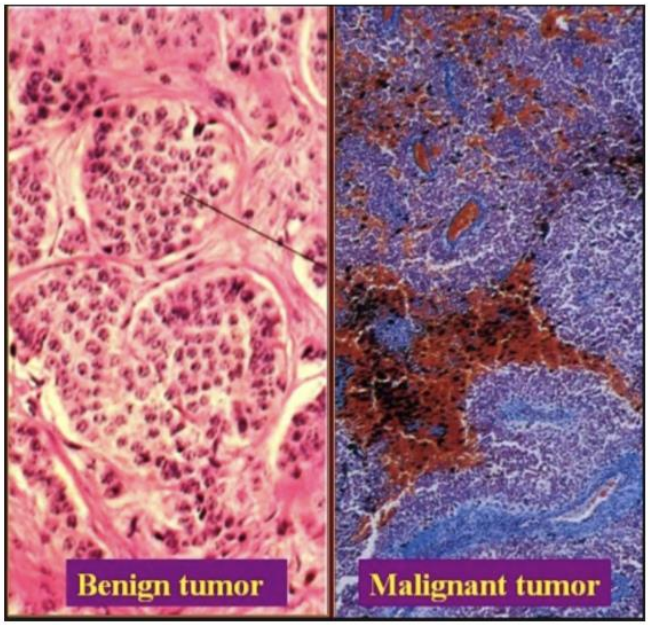




Linear Least Squares

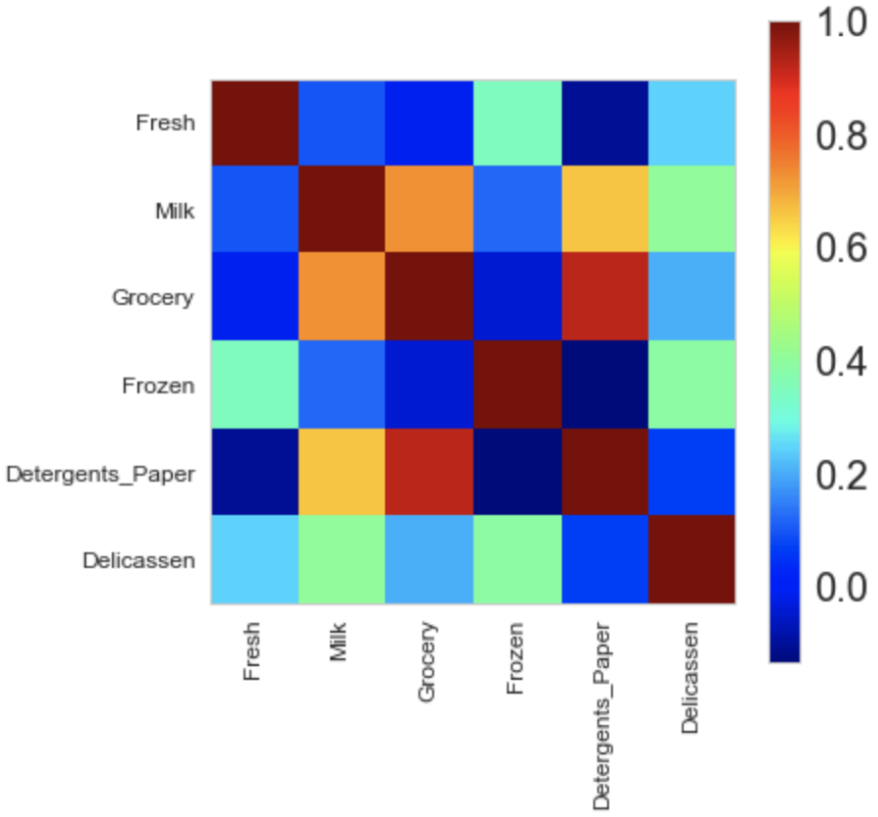
Dataset containing the characteristics of cells for several patients. Can we make predictions if cells are benign or malignant?

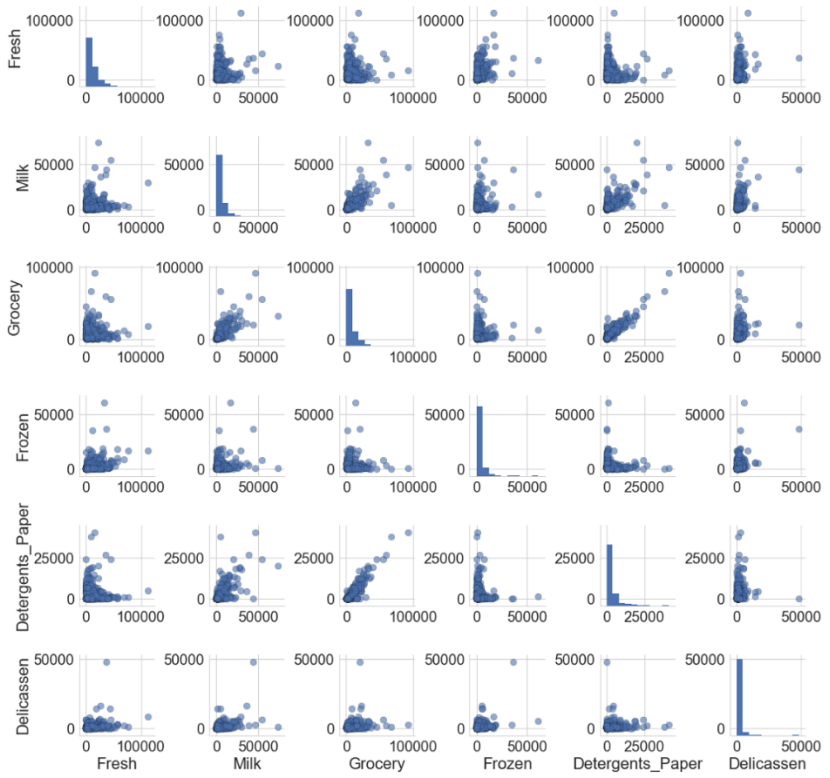




Principal component analysis

Sometimes our dataset has too many features? How can we reduce the feature space and still keep the most important information?





Second day of classes...

Assessments

	Available credit	Score
Module 3. Errors and Big-O		
L3 Errors, Big-O notation, plots	100% until 12:00, Tue, Jan 23	Not started
HW3 Errors and Big-O	100% until 23:59, Thu, Jan 25	0%
Module 2. Python		
L2 Introduction to Python	100% until 12:00, Tue, Jan 23	Not started
HW2 Introduction to Python	100% until 23:59, Tue, Jan 23	Not started
D2 Demo: Additional Python Tutorial	None	Not started
Module 1. Introduction		
L1 Introduction to CS 357 (NOT FOR CREDIT)	None	0%
HW1 Linear Algebra Review (NOT FOR CREDIT)	100% until 08:00, Tue, Jan 30	0%
D1 Demo: Intro to Numerical Methods	None	Not started

Week 1

Tue, Jan 16, lecture 1

Syllabus and Intro do CS 357

Complete your asynchronous lecture today!

L1: Introduction to CS 357 (NOR FOR CREDIT)
L2: Introduction to Python

Also opening today:

HW1: Linear Algebra Review (NOT FOR CREDIT)
HW2: Introduction to Python

Due today:

Thu, Jan 18, lecture 2

Python Intro + mock group work

Complete your asynchronous lecture today!

L3: Errors, Big-O notation, plots

Also opening today:

HW3: Errors and Big-O

Due today:

L2: Introduction to Python

L2: Introduction to Python

Total points: 0/2 — 0% — Available credit: 100% (Staff override)

Resources: Notes and complete slides

Question	Value	History	Awarded points
Self-guided notebook (no pre-recorded video)			
L2.1. Prerequisite survey	1		0/1
L2.2. Python intro - self-guided notebook	1		0/1

L2.2. Python intro - self-guided notebook

Open the workspace below and complete the IPython notebook.

Open workspace

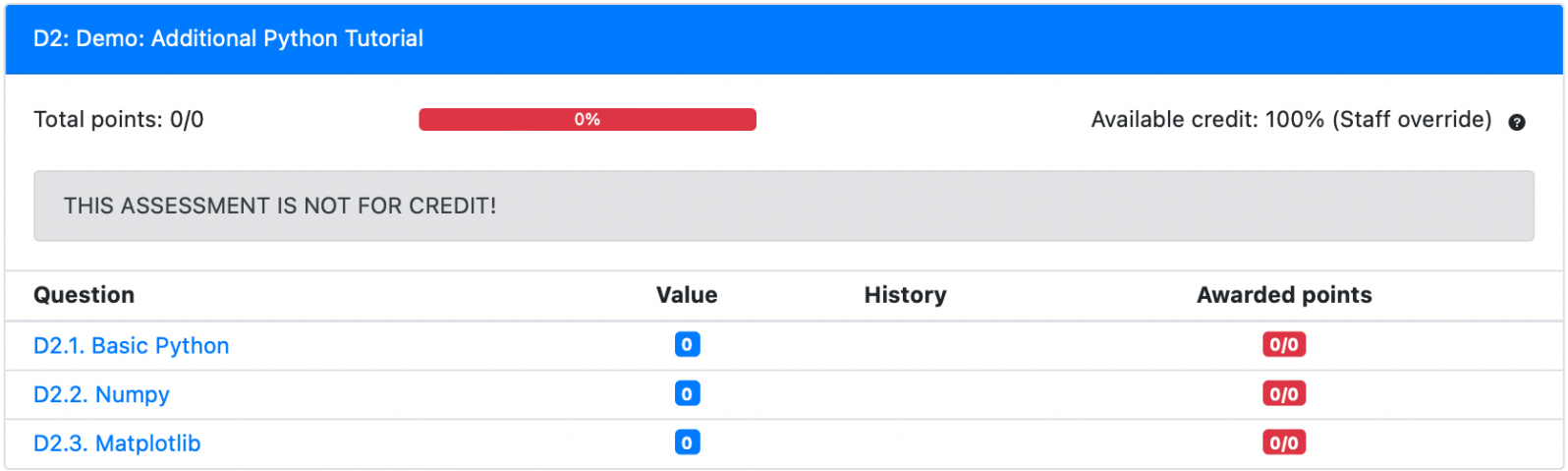
Select one of the answers below (there is no correct answer):

- (a) I completed the notebook, and I found it helpful.
- (b) I completed the notebook, but I did not find it helpful.
- (c) I did not complete the notebook because I already know how to use Python.
- (d) I did not complete the notebook (for other reasons).

Save & Grade *Single attempt* | Save only

Additional attempts available with new variants

D2: Additional Python Tutorial



For the Mock GA today, you will need to:

- Define Python variables
- Define 1d numpy array
- Perform simple operations with numpy arrays

Collaborative Learning

- Complete weekly activity in groups
- Week 1 and 2: randomly assigned groups via Zoom
- Starting from week 3: fixed groups

Supporting Collaborative Learning with Structured roles

Manager: keep team on task; enter the roles in PL

Recorder: enter most of the answers in PrairieLearn

Reflector: makes sure everyone is keeping up; complete survey

Consent was given for the media usage

When structured roles were required to alternate among group members…

- more equality in the work distribution among members
- groups scored better (on average a full letter grade
- groups completed work faster (on average 2.8 hours faster)

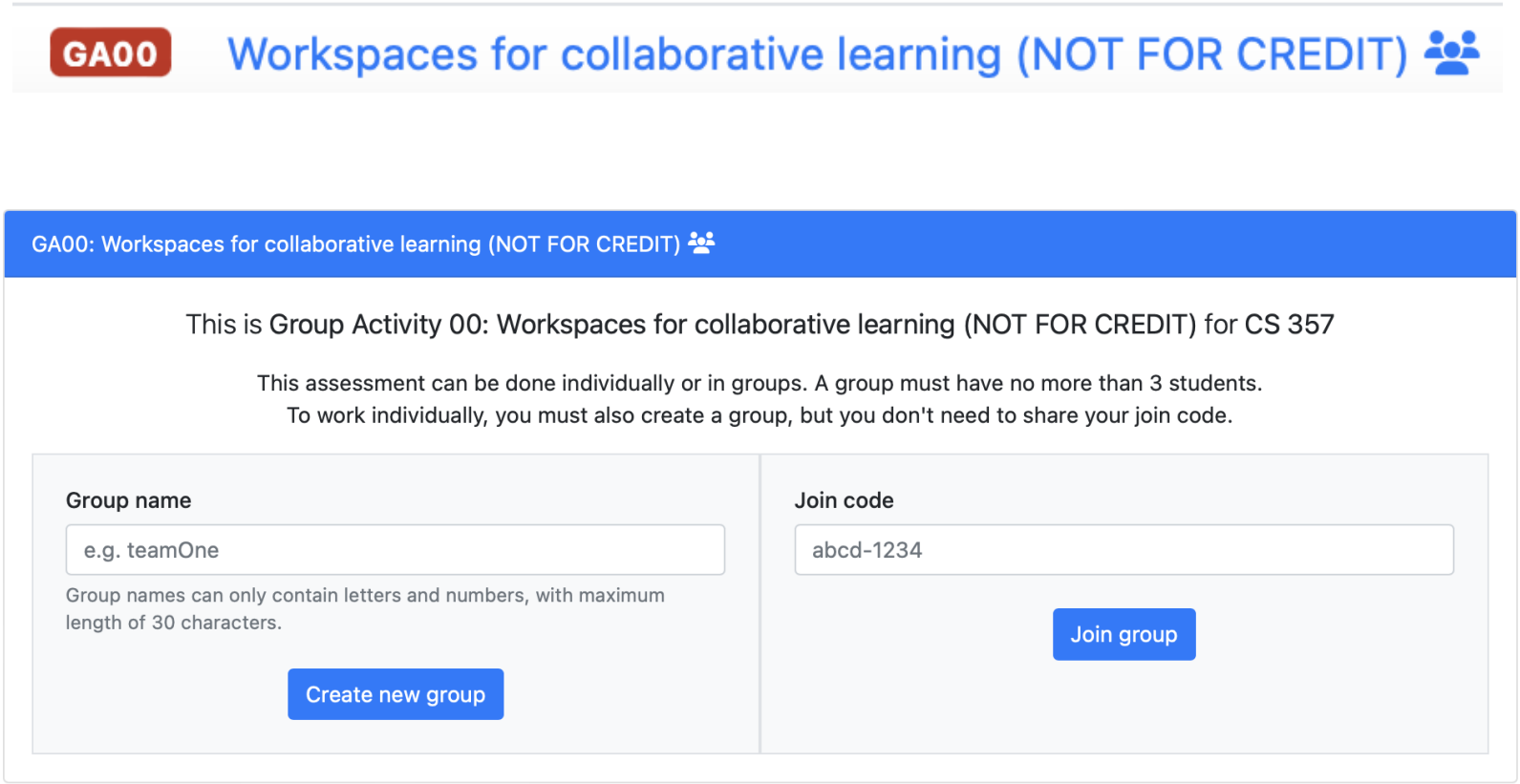
Meeting time preference (during class or another time on Tuesday)

- no significant effects on students' exam performance, sense of belonging or satisfaction regarding the course

Team consistency

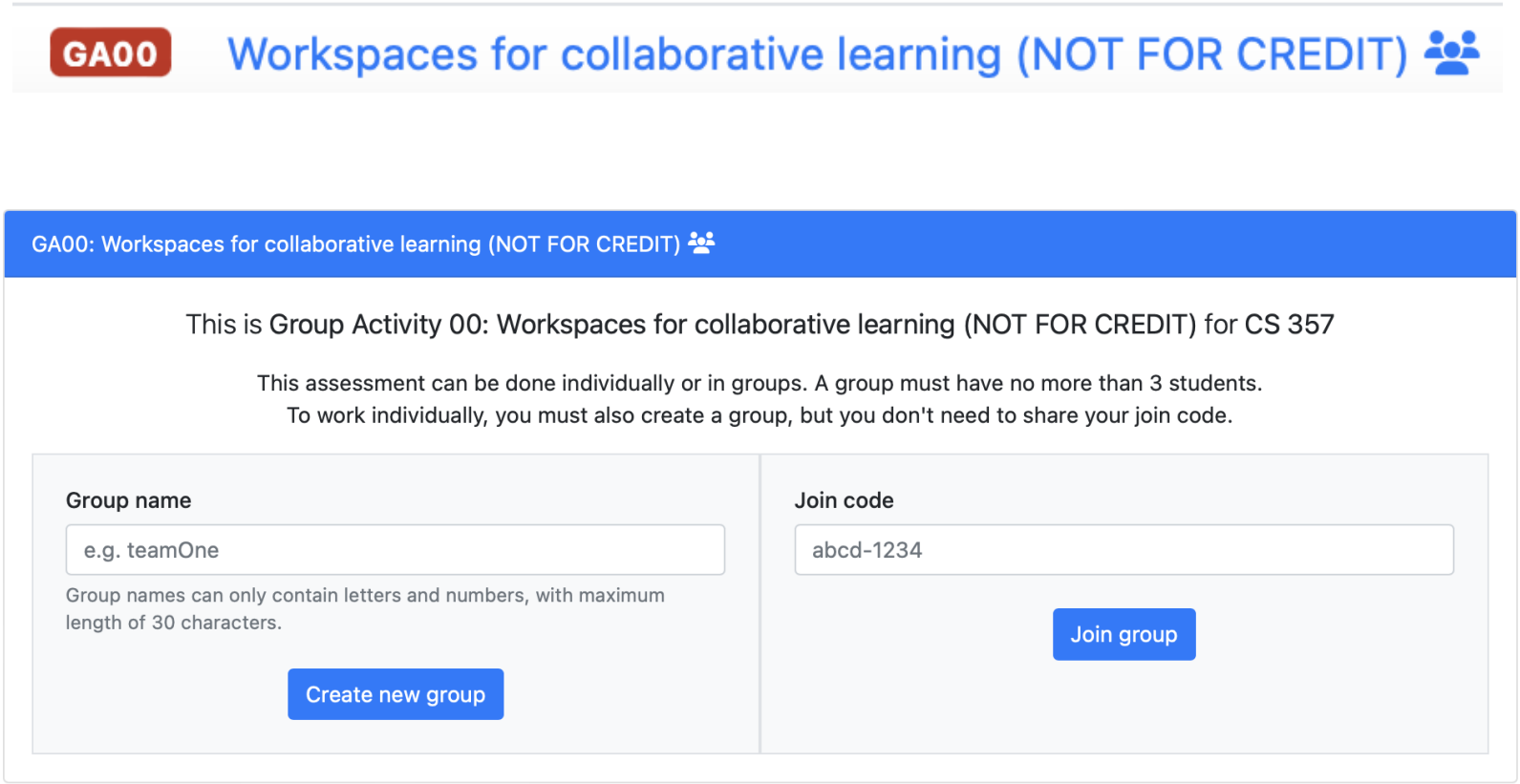
- positive effects on students' exam performance and sense of belonging, but not on satisfaction

Creating a group assessment in PL



We will go over this first mock GA.

Creating a group assessment in PL



You will now complete this GA with a random group. We will give you 7 minutes.

Creating the groups

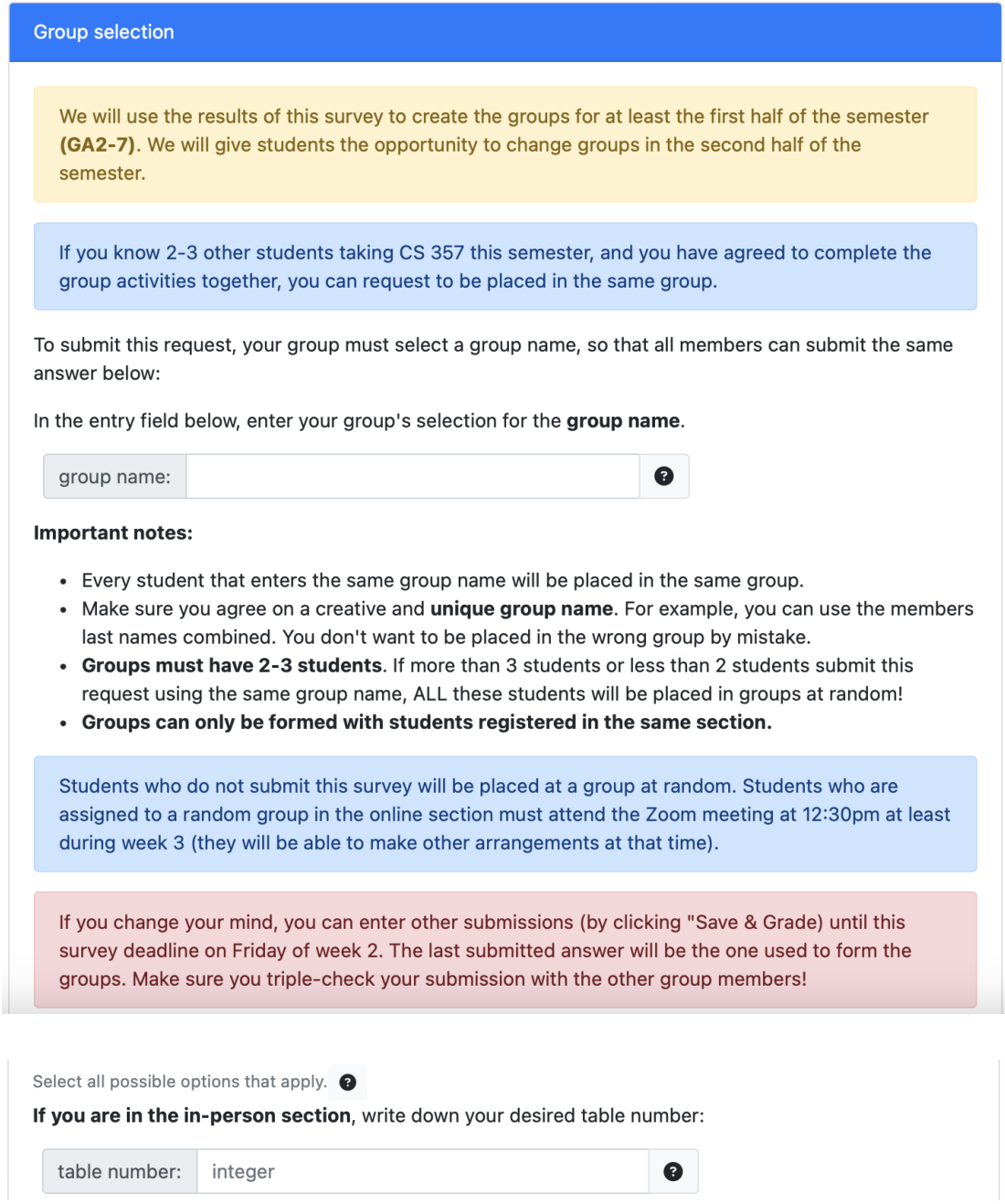
Course surveys

S1 Select your group (NOT FOR CREDIT)

Submit the survey by next Friday!

Students with time conflict override (not able to attend lecture at 12:30pm) MUST find a team that agrees to meet at a different time.

Fixed groups start on week 3



Group selection

We will use the results of this survey to create the groups for at least the first half of the semester **(GA2-7)**. We will give students the opportunity to change groups in the second half of the semester.

If you know 2-3 other students taking CS 357 this semester, and you have agreed to complete the group activities together, you can request to be placed in the same group.

To submit this request, your group must select a group name, so that all members can submit the same answer below:

In the entry field below, enter your group's selection for the **group name**.

group name:

Important notes:

- Every student that enters the same group name will be placed in the same group.
- Make sure you agree on a creative and **unique group name**. For example, you can use the members last names combined. You don't want to be placed in the wrong group by mistake.
- **Groups must have 2-3 students**. If more than 3 students or less than 2 students submit this request using the same group name, ALL these students will be placed in groups at random!
- **Groups can only be formed with students registered in the same section.**

Students who do not submit this survey will be placed at a group at random. Students who are assigned to a random group in the online section must attend the Zoom meeting at 12:30pm at least during week 3 (they will be able to make other arrangements at that time).

If you change your mind, you can enter other submissions (by clicking "Save & Grade) until this survey deadline on Friday of week 2. The last submitted answer will be the one used to form the groups. Make sure you triple-check your submission with the other group members!

Select all possible options that apply.

If you are in the in-person section, write down your desired table number:

table number: integer

Completing the GAs (Section N)

- Attendance at CIF 35 is required
- We will use the QR code from your Illinois App)
- You must not be late
- Total of 13 GAs
- Absences:
  - If you are ill, do not come to the classroom:
    - Make arrangements with your team to connect remotely
    - Submit a request for excused absence

DO NOT JOIN A GA IF YOU ARE NOT PARTICIPATING IN THE ACTIVITY (not in the classroom, or remote attendance due to illness). You will receive a zero in that GA.

Completing the GAs (Section M)

IF YOU PRE-SELECTED YOUR TEAM

- Your team can agree on a time and location to meet

IF YOU WERE ASSIGNED TO A RANDOM TEAM

- Your team must meet via Zoom during class time on week 3. You will need to make other arrangements for other weeks

TO GET SUPPORT

- GA support offered 11:00am to 12:15pm via Discord
  - 4 course staff monitoring real-time chat
  - 4 course staff monitoring voice channels
- Only team members participating in the completion of the GA can use the Join code.

Completing the GAs (Section M) - cont.

- Peer reviews (twice in the semester): answer these statements about yourself and teammates
  - Makes high quality contribution to the team's work
  - Asks for and shows an interest in teammates' ideas and contributions
  - Demonstrates knowledge of course content or actively asks questions when lost or confused
  - Motivates the team to do excellent work
  - I would gladly work with this individual in the future

Group roles

Practice Group Activity

GA 0 Get started with GAs (NOT FOR CREDIT)

If you need assistance during the group activity:

- Online between 12:30-1:45pm CT: post a message on the Queue, and please don't forget to add your Zoom breakout room number.
- In-person: raise your hand and a staff member will come to your table.

Learning Objectives

By the end of this GA, we hope that you will understand 1) how you should work collaboratively with your peers, and 2) how you should complete the jupyter notebooks and submit answers for grading.

Question	Value	History	Awarded points
Role assignments (Manager survey)			
GA 0.1. Define the roles for this group activity	1		— /1
Getting to know your group mates			
GA 0.2. Icebreaker	2		— /2
The group activity			
GA 0.3. Getting familiar with workspace	50		— /50
GA 0.4. Computing the final score	40		— /40
Debrief			
GA 0.5. Reflector survey: how did the activity go?	7		— /7