Adventures In Implementing Game-based Learning Models Into Core Engineering Curricula

Dr. Ali Ansari, PhD
12/21/2023

Today's Agenda!

- Who even am I?
- Introduction to Game-based Learning and Motivations!
- What could I improve upon?
- What worked?
- Some advice and tips for you all to start to play with it too!
- Future iterations!

Who am I?

- Hello Everyone! My name is Ali Ansari, if you didn't know that yet, and I am currently a Teaching Assistant Professor at the University of Illinois at Urbana-Champaign.

- I previously was a Visiting Assistant Professor at Bucknell University which is where I taught in both the Electrical and Computer Engineering Department as well as the Biomedical Engineering Department. Much of my content was made over there while I was teaching many of the core courses in their curricula.

- My expertise is in material science and cancer, but I am easily scientifically distracted, which means that I don't teach or do anything remotely related to those things, and have taught a wide range of courses from Probability to a Computational Methods (MATLAB) course, to Circuits, and even Signals and Systems in both BME and ECE departments.

- The main thrust of why I am doing this is that I have found that lowering the barrier of fear to many of these core materials may allow for students to feel more confident and may help with some of our issues of retention especially for minoritized populations which are also more likely to feel othered for a variety of reasons.

- One thing that I want to do is try to make the classrooms places where students can frame the knowledge they gain as tools, and give them a space to play with those tools and break things. When you can extend the use of complex tools into the most absurd situations, a lot of the fear is removed from it. So that's the main premise. Make it absurd.

What is Gameification and Game Based Learning?

- Okay, so now the reason that you are here today! I want to introduce something that I think many of you already know, but just in case, I wanted to introduce two similar concepts to you all. It's a little bit of a twist on active learning techniques that you may already be familiar with. These are Game based learning and its elder brother Gamification.
- Game based learning is the application of game based elements using games (in my case puzzles) to increase engagement and retention in education. In this the game is the vehicle in which you are delivering the learning objective.
- In contrast, you could apply game elements to the entire course instead of using a one off game as well. In this scenario you would have "leveling up" events and prizes and different collectibles that you could give students for reaching a goal, and even a leaderboard if you wanted to make it a more competitive environment. This would now be "Gamification". As you can surmise, this is a LOT of work.
- That being said, what I **have** implemented, game based learning, focuses on using these games to help contextualize the concepts for the students to more fully understand the motivations behind the rules.
- The central reasons for doing so is to increase engagement, allow for greater creativity in applications, and a different way of designing the course such that it is more accessible for students.

https://www.prodigygame.com/main-en/blog/game-based-learning/

How did I do it?

- So there were two main implementations that I used for Game based learning.
  - Lecture Integration
  - Lab Based Integration
- The way that they are integrated are slightly different, as I feel lab based integration lends itself far easier than lecture based ones in the sense that the *demonstration* is something that you are already doing in the lab portion.
- I will go over the what I did first and then end with some advice on how you can do it too! :)

Lecture Based Game Based Learning!

- Lecture based integration has been much harder, as labs are more conducive to the game-based design, while lecture suffers from a limitation of choice- if I implement more of these game, they will start to come at the cost of content in strictly scheduled core courses.
  - The way I dealt with this, is to integrate a weekly element that was supplemental to the lecture called “Puzzle Fridays”, a class competition to see who could score the most correct, who would be awarded a prize
  - These elements would allow me to lecture and cover the course material, but act as an application based method of testing retention in the students in an ungraded competition against the rest of the class.
- Another element that I have adopted is a variant on think pair share which is group-based discussion sections after every lecture to have the students explain some of the more theoretical elements to each other and then me as I met with each table to hear their individual answers.
- Obviously, this does not scale very well with larger and larger courses, so I tried to do a in class activity that was based on a cipher (hidden secret message) for students to solve using statistical questions. That works in limited fashions as well to motivate engagement.
- For one assignment with controls, I attempted to create a in class complicated game activity where each student had a different role in the system and brought multiple dice for them to use as different constants, but it got so complicated it didn’t help a lot of them. Next time we opt for more simple.
- This dovetails into another application which is student led journal clubs, which are completely led by the class with me choosing the content and the papers, but the students talking about how the papers intersect and what they mean contextually. This then evolved into a “dueling journal club” where I had each team read two papers and only half the class present on a specific one, so there were two “teams” and we would discuss the papers with them leading the conversation.

Lab Based Game Based Learning!

- In my computational class, I experimented with using MATLAB based puzzle labs.
  - These served the purpose of making MATLAB less intimidating, and making the rote portions of coding much more bearable.
  - Allowed students to see direct applications for the code that they were running, and how it was built.
  - Added a complicated Murder Mystery lab, which forced students to denoise images, solve MATLAB riddles, and apply different course elements.
  - This lab forced the students to implement all the current knowledge that they had to solve the puzzles.
  - One of the final labs was what I called the Uno Reverse Card lab, which asked students to create their own puzzles from the course materials and have at least one student in their lab section successfully complete the lab.
  - After the class, I collected exit surveys to try to quantify the confidence that they felt in their MATLAB coding, and all students greatly increased their comfort, with an 1.4 fold change from their initial average of 1.4, which means it more than doubled to 3.5.
- In my Probability course, I took what I learned from the previous iterations and implemented a few games and puzzle labs as well.
  - I was able to implement a lab where the students had to create code using cross-correlation but they had to use images of their own design to be able to customize it and get it to work.
  - I also implemented a lab where the students were able to test the distributions of m&m's to explain the chi squared error and how distributions may differ from the models that they have learned thus far.
- In my Signals and Systems course, I pushed as hard as I could to make as many of my labs game based learning exercises and found the students responded positively to them.
  - I was able to implement many labs where they had to experience the science or math in an orthogonal method other than what they had before, whether it was auditory, or visually, or having to sketch it, or even having to break it.
  - We got to have them play and record their favorite songs to analyze them in MATLAB, or have them draw pictures based on their answers from a bunch of Laplace Transforms.

Limitations of the Game based learning

- Okay, so this is all wonderful! You get to play with the science! They get to wonder at the infinite mysteries in our field! You get them to retain information in a more accessible way! *What could possible be wrong with this?*
- So, building these games is not a trivial amount of effort. It is much easier once you figure out a rhythm or a groove or avenue to start from, but my first few games were overwhelmingly difficult to start and build momentum.
- Games have a habit of running away from you. Sometimes when you are building the game element, you are so excited about the pretty new vehicle, you forget to put the engine in. Don't let the game take the spotlight too much from the material. From experience, sometimes simpler is better, especially for retention.
- LARGE CLASSES MAKE GAMES SO MUCH HARDER! Designing a game for 5-15 people is way different than 60+. It may not be feasible to even try to implement them when no one could play reasonably well in that time period due to the scale.
- Games need to take in account the diversity of the population that they are built for. That is to say, there is no one size fit all game. For example, one semester I built many different word based puzzles for my MATLAB course, which the students (and me) loved in the BIOE department. The next semester I tried to implement the same sorts of puzzles in a higher level Probability course in the ECEG department, and was addressed by some of my students asking if the word puzzles were mandatory because they were tedious. Confused, I realized that my word puzzles were not accessible for people who are international students or students with English as a second language. As the demographics of my course changed, I did not consider that the games themselves should have changed. The same can be said for color based elements for color blind students as well.
- Games require a certain amount of buy in from the students. They don't necessarily have to commit to it 100 percent, but if you give them something like *Twilight Imperium: Fourth Edition* and then expect them to learn that game and then the learning objective in 30 minutes, they're going to give up before they start.
- You are only human. Thinking up a NOVEL, ENGAGING, and RELEVANT puzzle every time is HARD. Also, you have to shoot the gap of making it neither universally hated nor boring, as making it universally loved is probably a pipe dream.

Successes

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[S, U, R, P, R, I, S, E, A, A, A, S, M, S, W, I, T, C, H, P, O, B, B, A, D]
[O, E, B, K, P, Z, X, L, O, B, J, E, A, C, P, O, E, H, U, E, N, O, H, D, F]
[U, C, K, L, K, D, F, O, A, H, K, L, B, I, I, U, S, N, U, N, O, I, D, A, C]
[H, O, W, M, A, N, Y, T, I, M, E, S, R, D, Q, P, I, E, F, N, E, W, E, E, K]
[J, B, V, C, O, M, P, U, T, E, T, E, O, N, T, T, T, T, T, S, L, T, W, E, L]
[L, R, S, O, B, G, E, B, V, A, T, I, X, U, Y, E, G, G, G, Y, O, J, R, B, K]
[K, A, D, O, D, R, F, C, E, D, T, F, G, M, Y, H, E, R, O, L, W, U, F, U, G]
[M, N, G, Y, H, Z, A, N, O, P, A, A, Z, E, B, C, Q, Q, Q, V, R, I, A, C, U]
[J, C, A, P, E, A, R, N, B, A, N, L, A, I, P, E, A, C, H, A, V, C, S, K, K]
[A, H, C, H, E, R, R, Y, C, A, M, H, S, B, K, I, W, I, S, N, A, E, G, N, M]
[U, R, E, S, G, B, E, L, I, E, V, E, G, A, I, B, L, E, A, N, G, M, Y, E, Y]
[E, W, E, E, K, C, O, N, F, I, D, E, N, C, E, E, E, E, E, I, E, E, O, L, U]
[C, T, G, E, N, I, U, S, C, O, C, H, A, R, O, C, H, A, I, A, B, R, U, L, I]
[O, G, X, B, M, E, G, R, O, C, K, S, O, U, D, O, N, U, T, O, S, X, G, U, F]
[B, E, B, L, E, A, C, H, P, L, E, S, B, I, O, N, E, P, I, E, C, E, O, N, D]
[H, A, D, M, F, L, O, V, I, E, Z, E, B, F, O, H, G, S, C, O, H, H, T, I, G]
[V, Q, A, M, G, A, P, X, Q, R, A, A, R, S, W, U, A, F, A, J, J, J, T, V, H]
[X, E, F, A, A, S, P, C, E, S, E, F, E, T, E, F, M, O, N, P, Q, Q, H, E, D]
[C, Q, Q, P, C, G, A, A, R, T, W, Z, A, A, C, O, E, R, D, W, W, W, I, R, S]
[S, W, R, A, V, A, F, R, T, A, Q, F, K, T, F, S, S, S, Y, F, P, F, S, S, D]
[R, I, U, G, B, E, G, J, I, S, E, S, B, E, F, L, W, T, R, Y, Y, E, P, I, V]
[G, C, O, H, U, L, R, O, O, T, N, T, I, M, R, O, H, R, J, C, G, G, P, T, F]
[E, H, A, A, L, I, E, K, N, U, D, A, S, E, U, O, I, W, F, G, E, E, W, Y, W]
[W, B, F, S, B, N, E, E, S, F, F, R, O, N, I, P, L, E, S, H, W, W, A, A, E]
[C, O, N, D, I, T, I, O, N, A, L, S, N, T, T, S, E, D, A, A, D, W, G, A, R]
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- Okay but, it is not all gloom and doom. Games have universally been used to lower the barrier of entry into many of these concepts.
- Through games, I have seen students who in their first day surveys told me that they didn't like coding, or were scared of it, or were trying to avoid it, do things like code the board game Battleship into MATLAB, or create a computational model demonstrating what selective hearing loss looks like. Confidence and play are powerful motivators.
- Through games, intimidating concepts or softwares can be broken down, even mocked and humbled. I have frequently shown students that the supposedly prim and proper MATLAB can be used to create such abominations as a word search all in symbolic variables. It was hell.
- And finally, through games, we can try to prevent students who feel othered, whether through their perceived lack of skill, or lack of belonging, or many other reasons, find an alternative way to engage in the material beyond the typical lecture and lab based models. It is an extension of the active learning techniques that we are ALREADY doing is all.
- It is something that students will REMEMBER. That alone helps with retention. If you make it a positive experience than it can also help them build confidence and expertise.

Tips and Tricks to try to start doing it yourself!

HOW TO MAKE YOUR OWN GAMES! Let's do an example!

1. Decide on a topic- what are you going to be talking about/focused on?
2. What are the learning objectives for this? What do you want them to master?

3. What is the game that you want them to play? What is the MEDIUM?

4. What are the ways you visualize this? How can they play with this and make it theirs? (Alignment)
5. How do you assess it?

If you noticed, this is the same thing that you already do when you lecture prep.
I just make it ABSURD. Here is a version of this exact lab:

Lab 6: Writing Music with Harmonies!

Due 03/21/2023 at 5 pm

This is a personal experience, but you can chat with your friends. And enemies.

Introduction

So my dream for this was to have y'all write your own music with the harmonies that you'd solve for using these programs, but unfortunately I don't enough MATLAB magic to create such majesty. Future me will level up and hopefully be able to do it one day.

Procedures

Today's lab is focused on teaching you all what a harmonic is other than just a fancy part of the Fourier Transform. In this, I want you to **hear** what a harmonic sounds like and how we can play with them and make our own bits of music along with identifying pieces of our favorite pieces and seeing if the code we cobbled together works or not. :)

CODE:

```
clc; clear all; close all;
[x,Fs]=audioread("Bucknell University 4.m4a");
x=x;
fs=Fs;
t = (0:size(x,1)-1)/fs;

winLength = round(0.05*fs);
overlapLength = round(0.045*fs);
[f0,idx] = pitch(x,fs,Method="SRH",WindowLength=winLength,OverlapLength=overlapLength);
tf0 = idx/fs;
figure
tiledlayout(2,1)

nexttile
plot(t,x)
ylabel("Amplitude")
title("Audio Signal")
axis tight

nexttile
pitch(x,fs,Method="SRH",WindowLength=winLength,OverlapLength=overlapLength)
title("Pitch Estimations")
hr =
harmonicRatio(x,fs,Window=hamming(winLength,"periodic"),OverlapLength=overlapLength);

figure
tiledlayout(3,1)

nexttile
plot(t,x)
ylabel("Amplitude")
title("Audio Signal")
axis tight

nexttile
pitch(x,fs,Method="SRH",WindowLength=winLength,OverlapLength=overlapLength)
title("Pitch Estimations")
xlabel("")

nexttile
harmonicRatio(x,fs,Window=hamming(winLength,"periodic"),OverlapLength=overlapLength)
title("Harmonic Ratio")
threshold = 0.9;
f0(hr < threshold) = nan;

figure
plot(tf0,f0)
xlabel("Time (s)")
ylabel("Pitch (Hz)")
title("Pitch Estimations")
grid on
```

Note	Frequency (Hz)	Note	Frequency (Hz)	Note	Frequency (Hz)
C_0	16.35	A_2	110.00		
$C^{\#}_0/D^{\flat}_0$	17.32	$A^{\#}_2/B^{\flat}_2$	116.54	$F^{\#}_5/G^{\flat}_5$	739.99
D_0	18.35	B_2	123.47	G_5	783.99
$D^{\#}_0/E^{\flat}_0$	19.45	C_3	130.81	$G^{\#}_5/A^{\flat}_5$	830.61
E_0	20.60	$C^{\#}_3/D^{\flat}_3$	138.59	A_5	880.00
F_0	21.83	D_3	146.83	$A^{\#}_5/B^{\flat}_5$	932.33
$F^{\#}_0/G^{\flat}_0$	23.12	$D^{\#}_3/E^{\flat}_3$	155.56	B_5	987.77
G_0	24.50	E_3	164.81	C_6	1046.50
$G^{\#}_0/A^{\flat}_0$	25.96	F_3	174.61	$C^{\#}_6/D^{\flat}_6$	1108.73
A_0	27.50	$F^{\#}_3/G^{\flat}_3$	185.00	D_6	1174.66
$A^{\#}_0/B^{\flat}_0$	29.14	G_3	196.00	$D^{\#}_6/E^{\flat}_6$	1244.51
B_0	30.87	$G^{\#}_3/A^{\flat}_3$	207.65	E_6	1318.51
C_1	32.70	A_3	220.00	F_6	1396.91
$C^{\#}_1/D^{\flat}_1$	34.65	$A^{\#}_3/B^{\flat}_3$	233.08	$F^{\#}_6/G^{\flat}_6$	1479.98
D_1	36.71	B_3	246.94	G_6	1567.98
$D^{\#}_1/E^{\flat}_1$	38.89	C_4	261.63	$G^{\#}_6/A^{\flat}_6$	1661.22
E_1	41.20	$C^{\#}_4/D^{\flat}_4$	277.18	A_6	1760.00
F_1	43.65	D_4	293.66	$A^{\#}_6/B^{\flat}_6$	1864.66
$F^{\#}_1/G^{\flat}_1$	46.25	$D^{\#}_4/E^{\flat}_4$	311.13	B_6	1975.53
G_1	49.00	E_4	329.63	C_7	2093.00
$G^{\#}_1/A^{\flat}_1$	51.91	F_4	349.23	$C^{\#}_7/D^{\flat}_7$	2217.46
A_1	55.00	$F^{\#}_4/G^{\flat}_4$	369.99	D_7	2349.32
$A^{\#}_1/B^{\flat}_1$	58.27	G_4	392.00	$D^{\#}_7/E^{\flat}_7$	2489.02
B_1	61.74	$G^{\#}_4/A^{\flat}_4$	415.30	E_7	2637.02
C_2	65.41	A_4	440.00	F_7	2793.83
$C^{\#}_2/D^{\flat}_2$	69.30	$A^{\#}_4/B^{\flat}_4$	466.16	$F^{\#}_7/G^{\flat}_7$	2959.96
D_2	73.42	B_4	493.88	G_7	3135.96
$D^{\#}_2/E^{\flat}_2$	77.78	C_5	523.25	$G^{\#}_7/A^{\flat}_7$	3322.44
E_2	82.41	$C^{\#}_5/D^{\flat}_5$	554.37	A_7	3520.00
F_2	87.31	D_5	587.33	$A^{\#}_7/B^{\flat}_7$	3729.31
$F^{\#}_2/G^{\flat}_2$	92.50	$D^{\#}_5/E^{\flat}_5$	622.25	B_7	3951.07
G_2	98.00	E_5	659.25	C_8	4186.01
$G^{\#}_2/A^{\flat}_2$	103.83	F_5	698.46	$C^{\#}_8/D^{\flat}_8$	4434.92

D_8	4698.63
$D^{\#}_8/E^{\flat}_8$	4978.03
E_8	5274.04
F_8	5587.65
$F^{\#}_8/G^{\flat}_8$	5919.91
G_8	6271.93
$G^{\#}_8/A^{\flat}_8$	6644.88
A_8	7040.00
$A^{\#}_8/B^{\flat}_8$	7458.62
B_8	7902.13

Table Sourced from: https://pages.mtu.edu/~suits/notefreqs.html
There are many online keyboards and Idk which are safe, here is one I used but maybe its dangerous idk:
https://virtualpiano.net/

Let's try it again with an actual song! See if you can find the three or so main notes in this! :)
Import the Bucknell5 file into your MATLAB and run it again! Can you reconstruct the song using those notes? :D

_____
_____
_____
_____

Task 3: Pick your favorite song and identify some fundamental frequencies in it!

Again, this is what has taken me the longest time to make and I hope that it works. Here, I want you to record between 5-10 seconds of one of your favorite songs via the Voice Recording app on your phone (I only tried it on apple, but try it on your windows phone and we shall see) and then share it with your email.

Once you have it, import it into Matlab with the function audioread('INSERTNAME') and then run our program that we wrote for part two above. Find me some of the frequencies, and then using that please tell me what other frequencies you know are in the song. Please feel free to use the table to listen to the different notes that are in your song from the fundamental frequencies that you are finding. Do some sound better when you play them at the same time and are they related somehow mathematically?

_____
_____
_____
_____
_____

Examples of my stuff!

- “Okay, but that was just one exercise! And one ‘game’.”
- “What else you got?”

Here is a short list of the games that I have made, with hyperlinks to a folder if you wanna take a look at it. I don’t know how intellectual property stuff works, but if you want to use something, please let me know and we can chat. I don’t mind you doing so if you think it will help the kids though.

1. Midterm project that involves me singing and them isolating my voice out of a large amount of noise.
2. Final project which involves my voice being the noise to remove and them developing custom filters to remove it.
3. Word Scramble MATLAB Puzzle involving Vectors
4. Secret Message Cipher MATLAB Puzzle involving Matrix Math
5. Crossword with Secret Message MATLAB Puzzle involving Matrix Operations
6. Abomination Word Search using MATLAB involving Loops and Conditional Logic
7. Midterm Review Lab Murder Mystery in MATLAB
8. Sudoku MATLAB Puzzle involving Vector and Matrix Math
9. An example of a Puzzles Friday Lecture where students had to identify extant circuits
10. Crossword with Secret Message for Lab One MATLAB refresher
11. Sandbox based Puzzle involving Linear Transformations
12. Sketching and Secret Message based Puzzle involving Laplace Transforms
13. Sketching and Visualizing Convolution and Filters in MATLAB
14. Whodunnit involving Fourier Transform Math in MATLAB
15. The Lab that we made together in its completed form in MATLAB involving frequencies and FFTs in MATLAB
16. DND Inspired MATLAB Program for Stability and Feedback Investigation

Examples of Games and Puzzles!

Word Based Puzzles!	Math Based Puzzles!	Coding/ MATLAB based Puzzles!
Word Searches	Drawing or Sketching	Murder Mystery/Multipart Puzzles using skills from lectures
Crosswords	Sudoku Puzzles	Program based exercise
Word Scrambles	Binary/Hexadecimal Conversion to ASCII	Visualization based Puzzles
Hidden Messages	Probability/Experimentation Puzzles with Dice or Coins	Open Ended Creative Programs
Ciphers		

Future Aims and Design Ideas

- So, what am I doing next? EXCELLENT QUESTIONS. I want to build a bank of these types of games.
- My research in graduate school was in designing a customizable tool for researchers, and I feel this is the same concept but for teachers. I want to make a scaffold so that others can help teach in a manner that will help our students learn in a safe and fun environment.
- So in my spare time, I am cobbling together ideas, and eventually going to try to write a paper on this. I promise.
- I would love any and all ideas that you all think would help or direct this. BUT FIRST LET ME GET YOU TO WHAT YOU CAME HERE FOR!

Quick Recap!

Okay, so to recap:

- I have created some game based learning models for my courses in order to try to help with issues of retention, attrition, and belonging in STEM courses.
- Game based models are great and fun, but have a variety of weaknesses as well as strengths that we should keep in mind when we design them. There are no perfect games for your class.
- I would love any and all feedback on this, and welcome you to look at any of the material I have generated. If you have more questions, I can provide more stuff such as the MATLAB code, which I have placed somewhere.
- Thank you very much for your time and attention!

What Courses did I teach content in?

- So as I mentioned, I have taught in a variety of disciplines. Here are the courses that I tried to implement Game-based learning in:
- In Bioengineering/Biomedical Engineering:
  - BMEG 220- Introduction to Engineering Computing- Bucknell University, Lewisburg, PA
  - BMEG 350- Fundamentals of Biomedical Signals and Systems-Bucknell University, Lewisburg, PA

- In Electrical and Computer Engineering:
  - ECEG 270- Signals and Systems Theory-Bucknell University, Lewisburg, PA
  - ECEG 351- Electronic Circuits II- Bucknell University, Lewisburg, PA
  - ECEG 370-Probabilistic System and Data Analysis- Bucknell University, Lewisburg PA
  - ECEG 470- Communication and Information Systems-Bucknell University, Lewisburg, PA

Student Testimonials!

- “I personally really enjoyed doing the puzzle style labs! I find coding very very overwhelming so I think a much more rigid or regimented coding lab would make me feel really tense and stressed in comparison to the puzzles. The puzzles helped break down coding concepts into smaller parts, made it much more enjoyable, and was a super unique experience in a lab.”

- “I do think the puzzles were very helpful while I was learning matlab. It made the process a lot more enjoyable and many times I forgot I was learning along the way. The puzzles helped me cemen[t] the lecture material and really put everything together. Also, I just enjoyed doing them and it made the labs a lot of fun to come to. The atmosphere was also one that we were all able to work together and learn but still joke and have a good time. I do not think a structured computer science approach would have helped me as much. I believe I would have quickly gotten the work done so that I could leave. Whereas there were times I stayed and did the optional part of the puzzle or I did multiple peoples puzzles when it was not necessary. It kept me engaged and eager to learn. “

- “I think the puzzles were a fun way to learn that kept me engaged. I was able to execute the functions and concepts from the lecture while having a good time. The puzzles made it easier for me to see what was happening without getting bored or overwhelmed at huge portions of code. I am not totally sure what a structured computer science approach would have looked like since I have not taken a computer science course, but I did like the engagement on these activities in lab, so I think for other kids like me who do not have a structured computer science background, it would be fun and helpful to continue learning in this way.”

- “I do believe the puzzles were extremely helpful in learning how Matlab functions. They were a fun way of engaging us in applying what we learned in class. It led into a different way of thinking about how the commands and functions worked, which is much better than muscle memory coding.”