

# Warm-up question

- In your own words, **what is research?**

Spring 2019

Mike Lam

# "What is Research?"

Seminar Talk

# Warm-up question

- In your own words, **what is research?**

(answers courtesy of my CS 470 class)

# What is research?

- *“Research is the process of finding information.”*
- *“Research is when you use your own time to understand and describe in words a topic you did not know about before.”*
- *“Looking for credible information pertaining to a specific topic.”*
- *“Utilization of academic, peer-reviewed publications in order to better understand or solve a problem.”*
- *“It's taking concepts or ideas and collecting valuable information pertaining to it, with some fact checking of course!”*

# What is research?

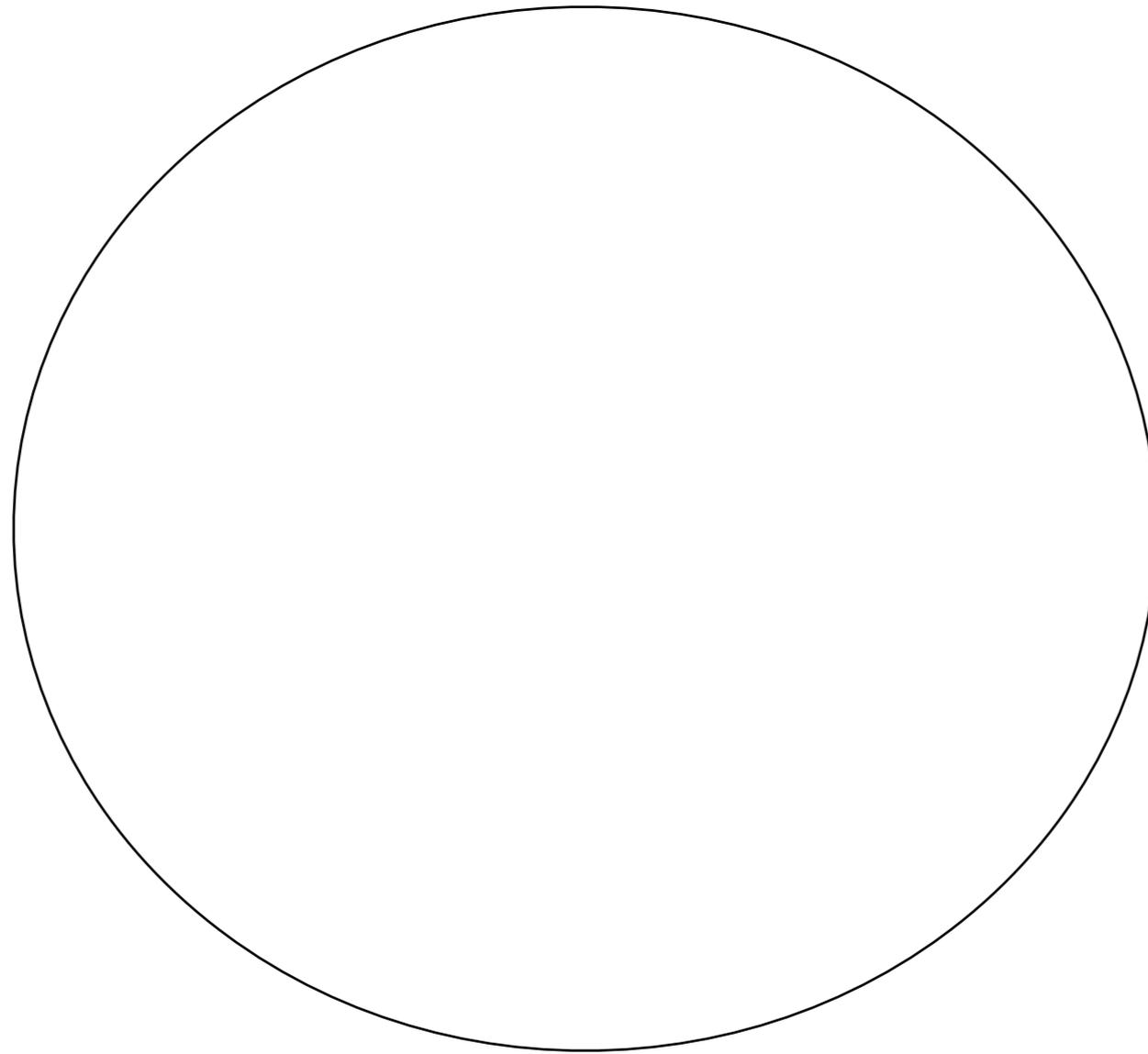
- *“Working at the edge of knowledge in a field attempting to push that frontier a little further with your work.”*
- *“Thorough investigation into a subject, with the end result of finding new information.”*
- *“Research is building on the work of others on a topic of the researchers choice to posit new arguments and find new discoveries that might interest yourself or the general public.”*
- *“Learning new things then doing those things then writing about those things.”*

# What is research?

- The former is **secondary** research
  - Wikipedia: "*summary, collation and/or synthesis of existing research*"
- The latter is **primary** research
  - OECD 2015: "*creative and systematic work undertaken to increase the stock of [human] knowledge*"
  - Goal: **novelty!**
  - Many subcategories:
    - Purpose: **theoretical** vs. **applied**
    - Target: **formal** vs. **natural** vs. **social**
    - Methodology: **scientific** vs. **historical** vs. **artistic**

# Knowledge (visualized)

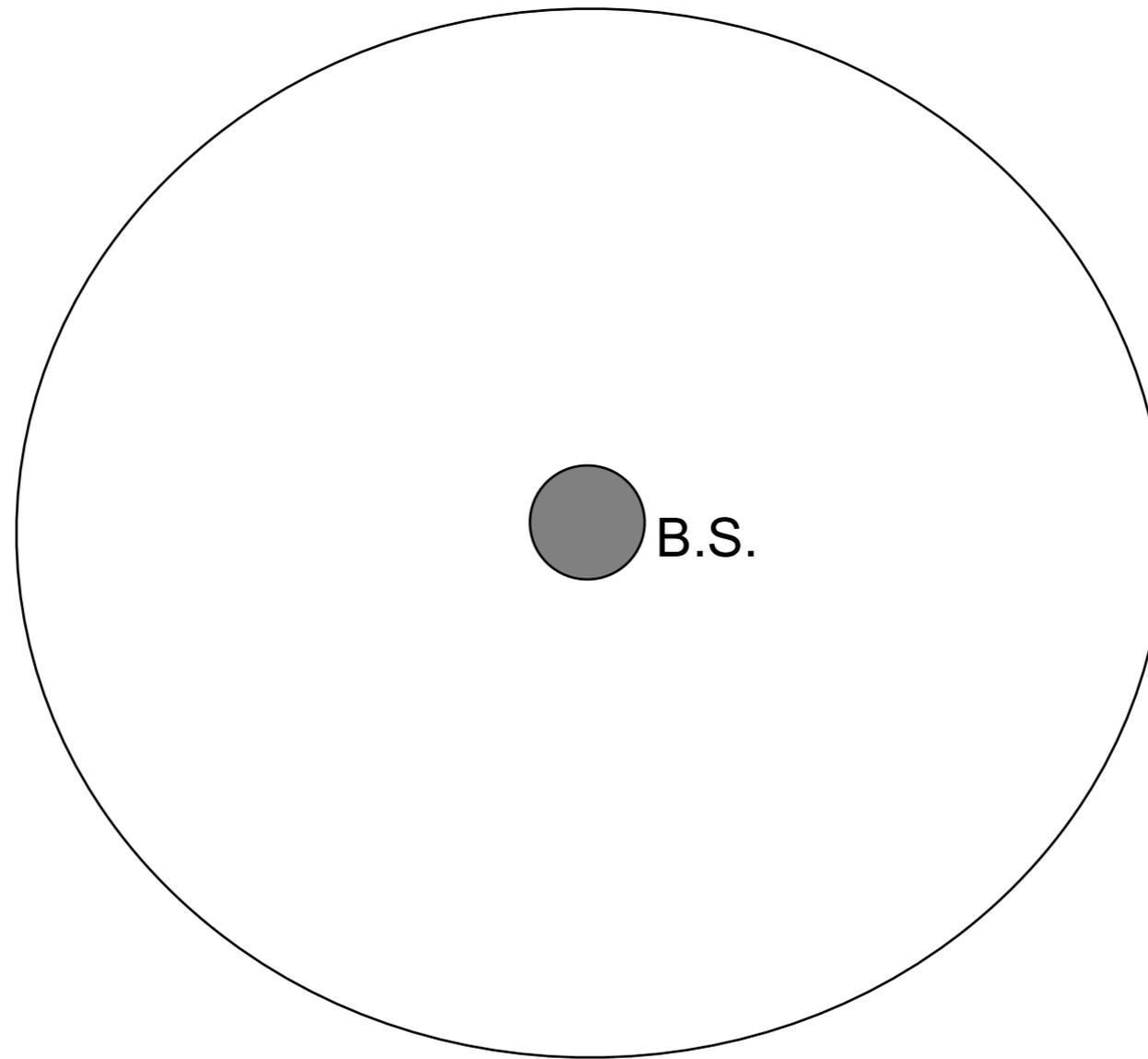
all current human CS knowledge



based on <http://www.happyschools.com/bachelors-vs-masters-vs-phd/>

# Knowledge (visualized)

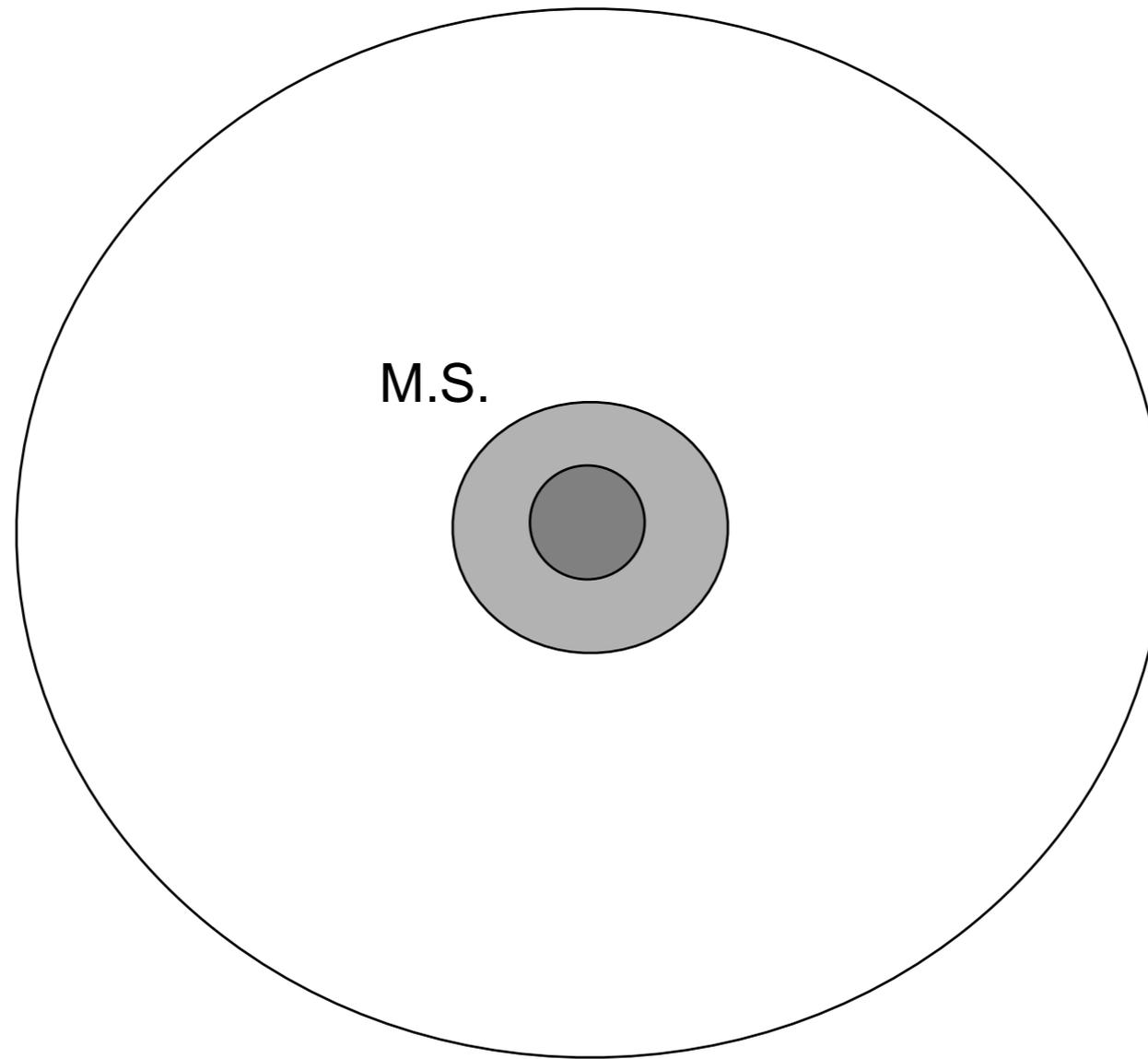
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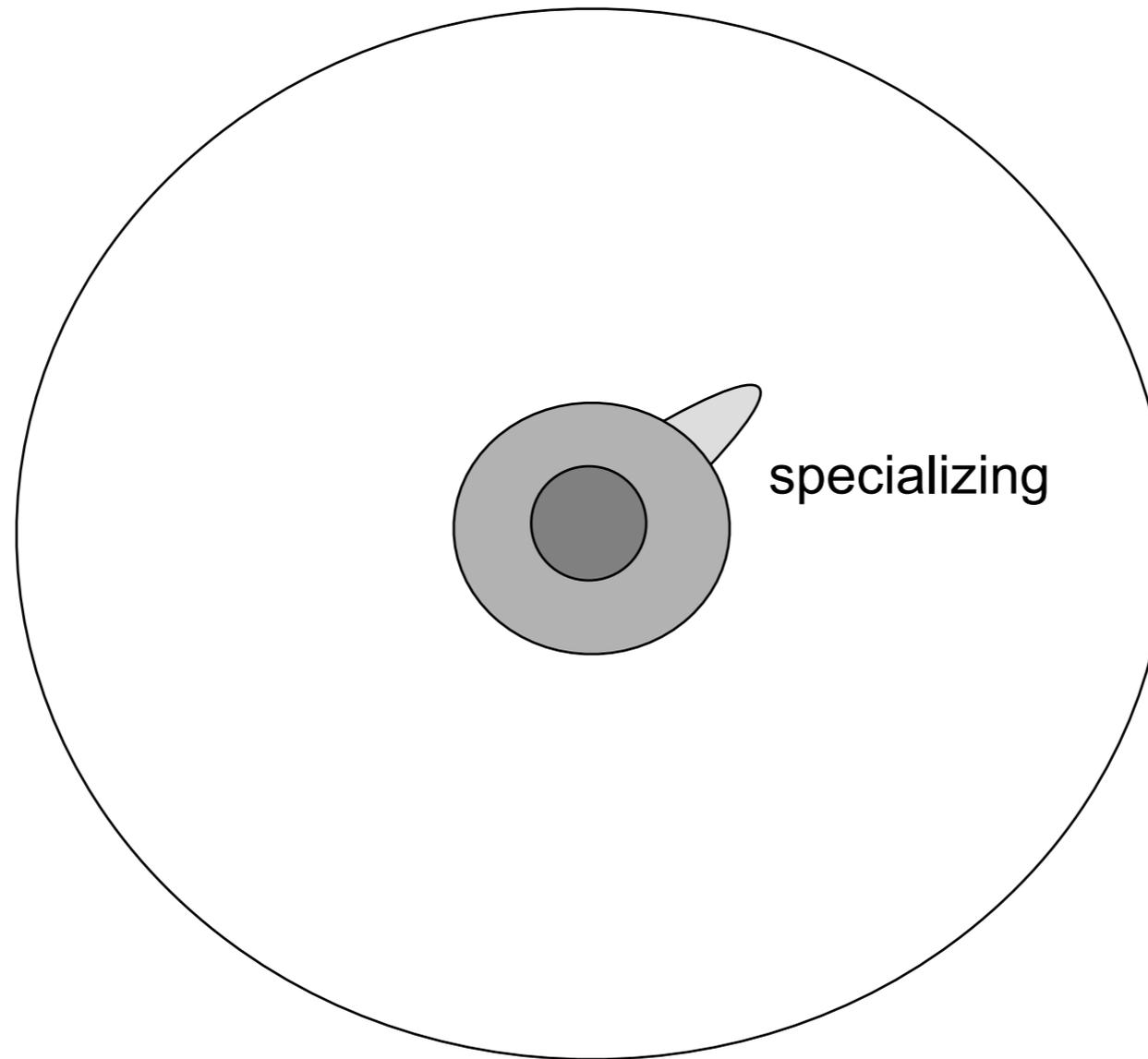
# Knowledge (visualized)

all current human CS knowledge



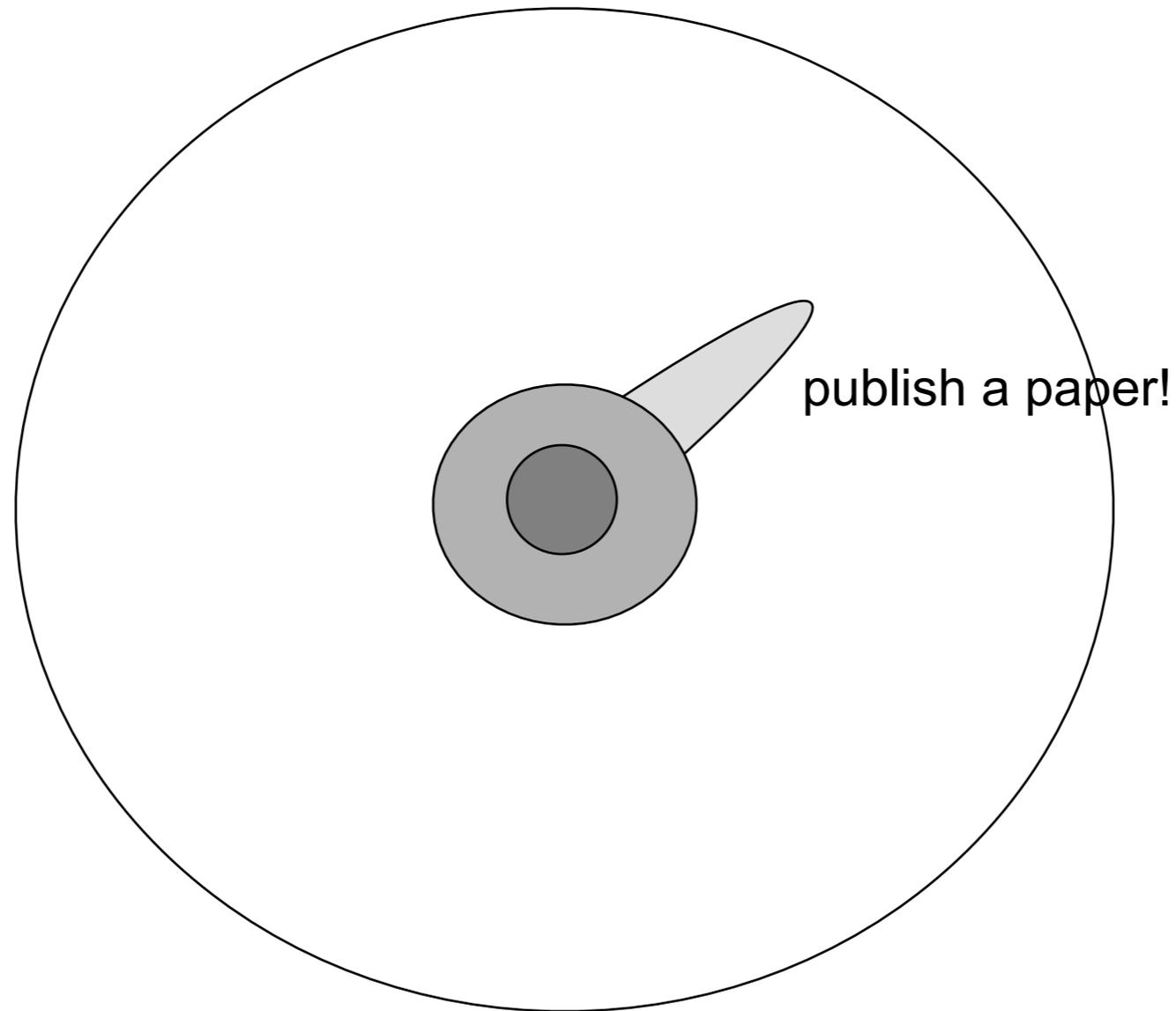
# Knowledge (visualized)

all current human CS knowledge



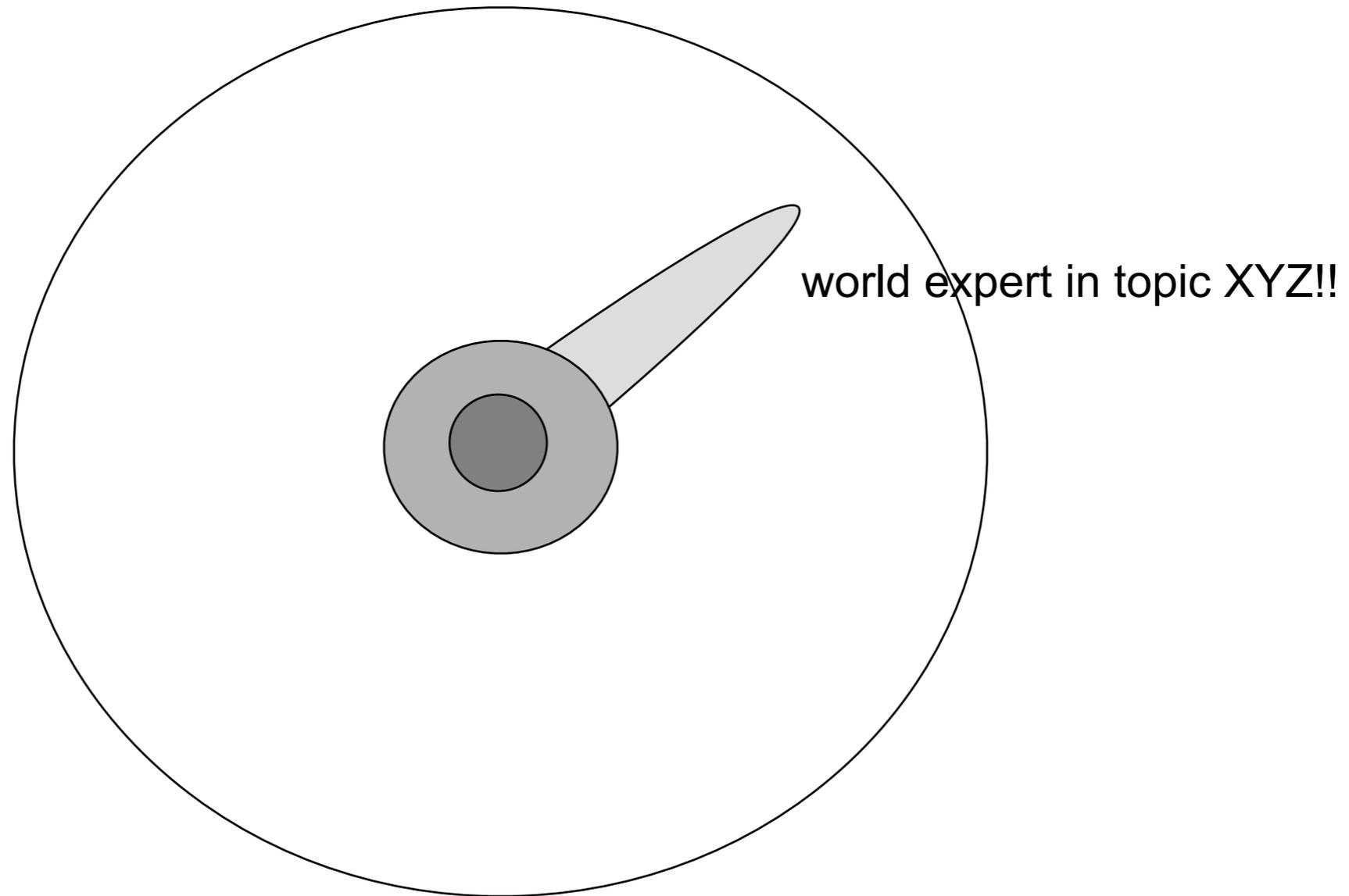
# Knowledge (visualized)

all current human CS knowledge



# Knowledge (visualized)

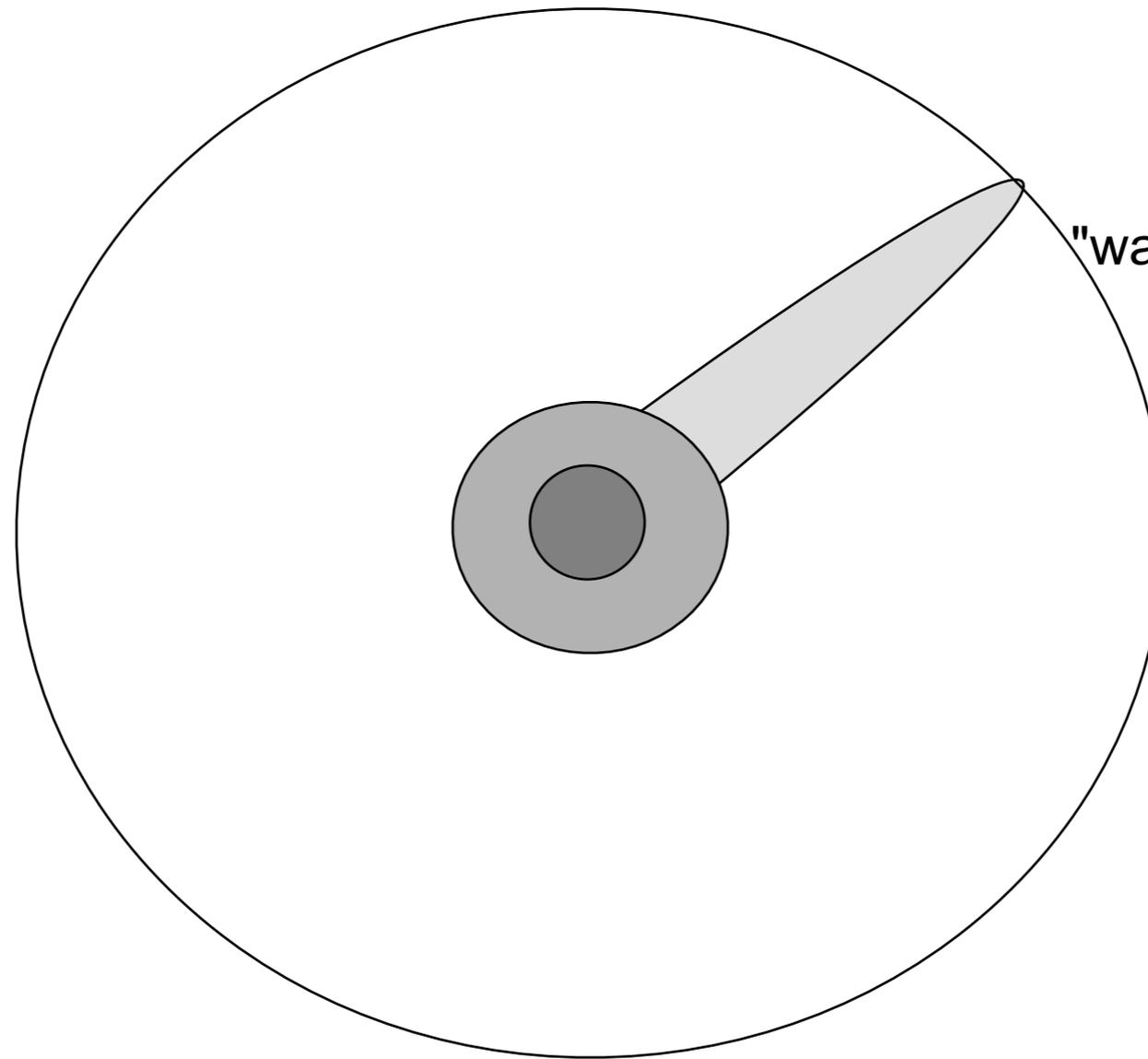
all current human CS knowledge



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# Knowledge (visualized)

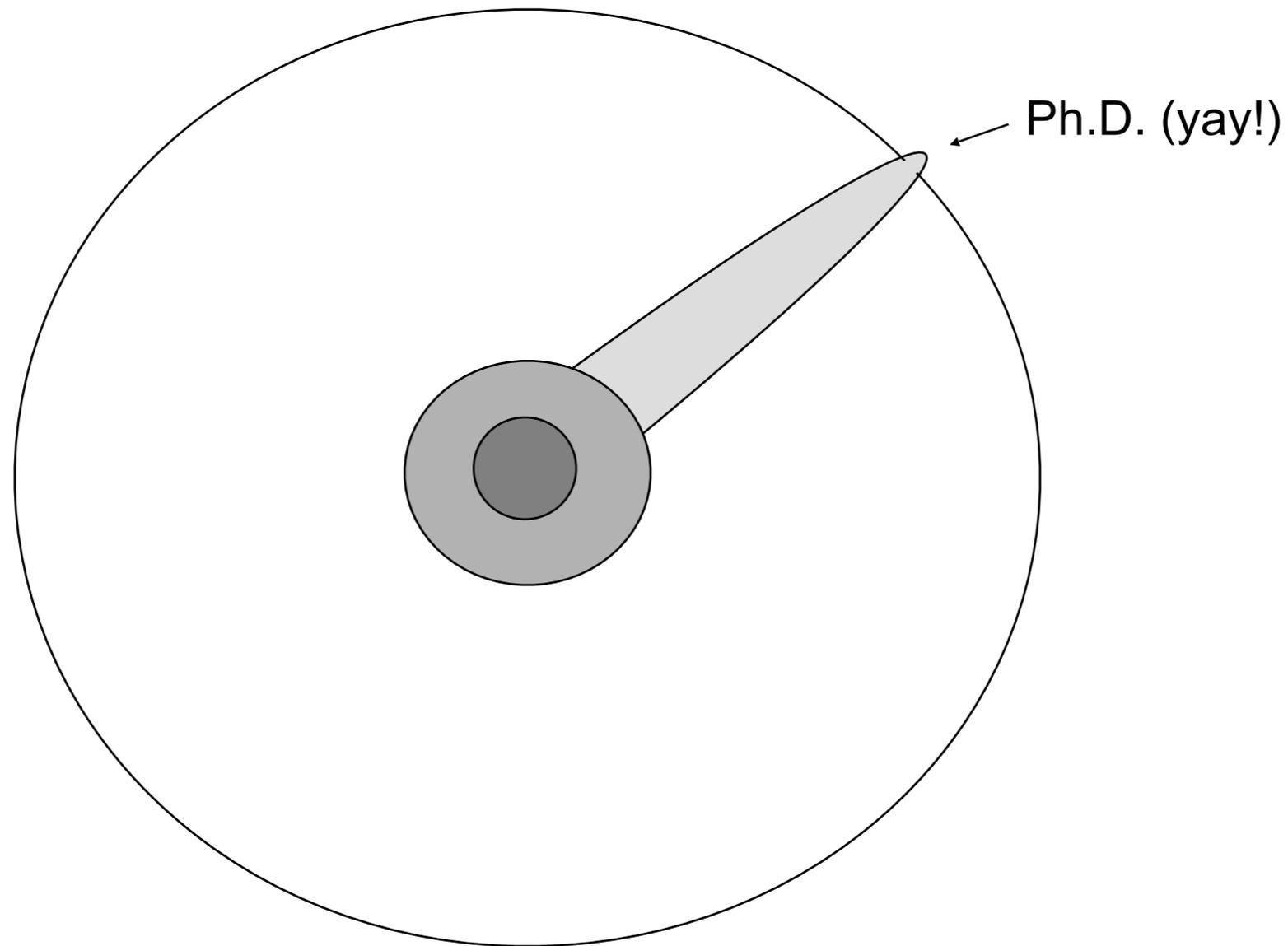
all current human CS knowledge



"wait, you're still in school?!?"

# Knowledge (visualized)

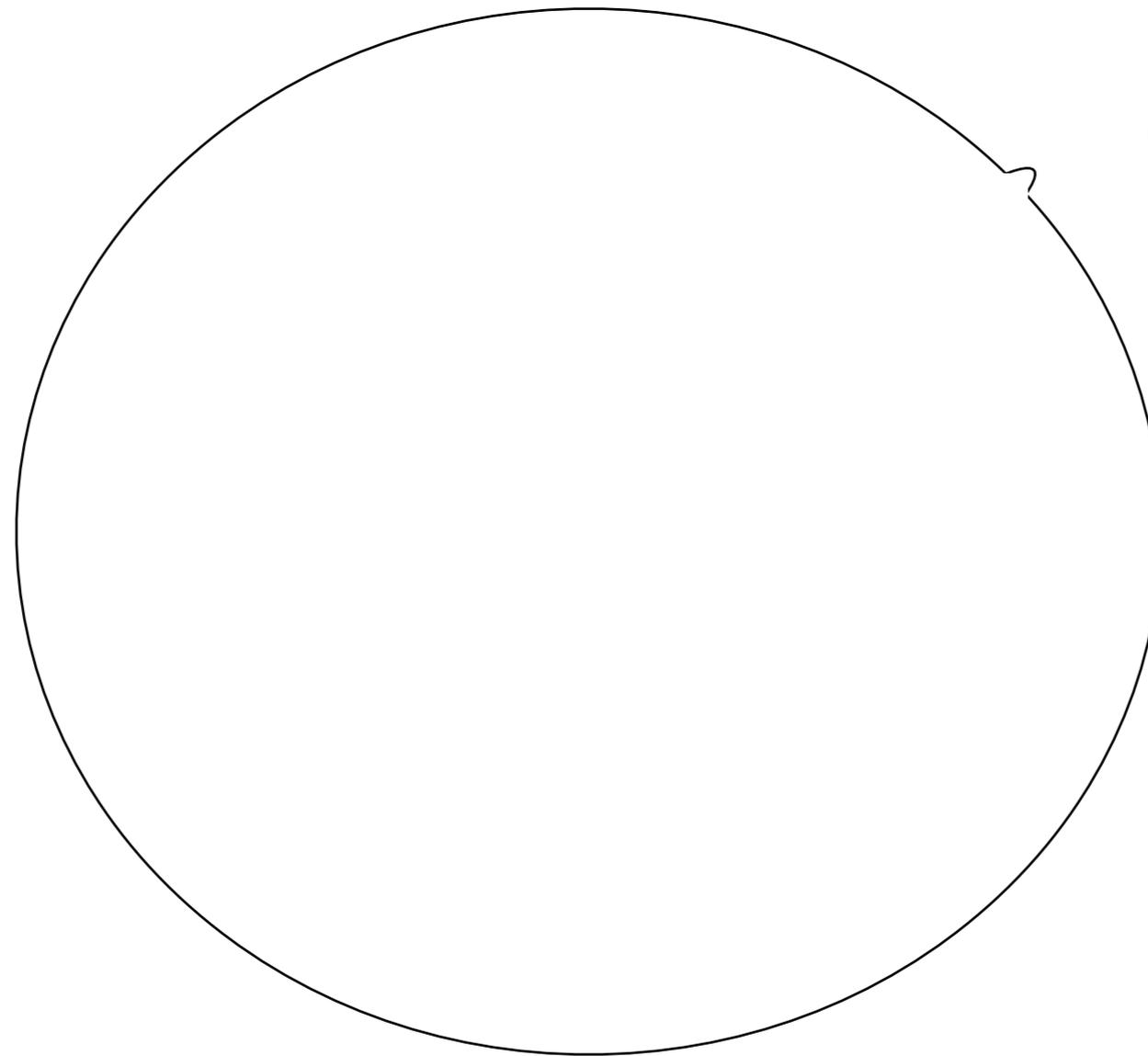
all current human CS knowledge



based on <http://www.happyschools.com/bachelors-vs-masters-vs-phd/>

# Knowledge (visualized)

all current human CS knowledge



(the big picture)

# Another perspective

- As faculty advisors ...
  - Undergrad projects: we have a reference solution
  - Graduate projects: we know a solution is possible
  - Research projects: we think a solution *might* be possible

# What is research?

- *“Research is the process of systematically casting a fishing rod into the unknown and hoping that you reel in something worthwhile.*

*Sometimes you catch nothing, sometimes you get something worthwhile, and sometimes you get something that looks worthless until it's published by somebody else three years later.*

*But regardless you slowly begin to learn about the world on the other end of that hook.”*

# If that is what, now how?

- My advisor from UVA (Bill Wulf)
  - “We don’t really know how so we use the apprentice model.”
- More detailed references
  - How to pick an advisor
    - [“Getting Started in Undergraduate Research”](#)
  - How to read a paper
    - [“How to Read an Engineering Research Paper”](#)
- What I wish I knew/organization
  - [“Organizing your Research and Developing your Research Skills”](#)
  - [“Everything I Wanted to Know about CS Graduate School at the Beginning but Didn’t Learn Until Later”](#)

# Dr. Dee A. B. Weikle

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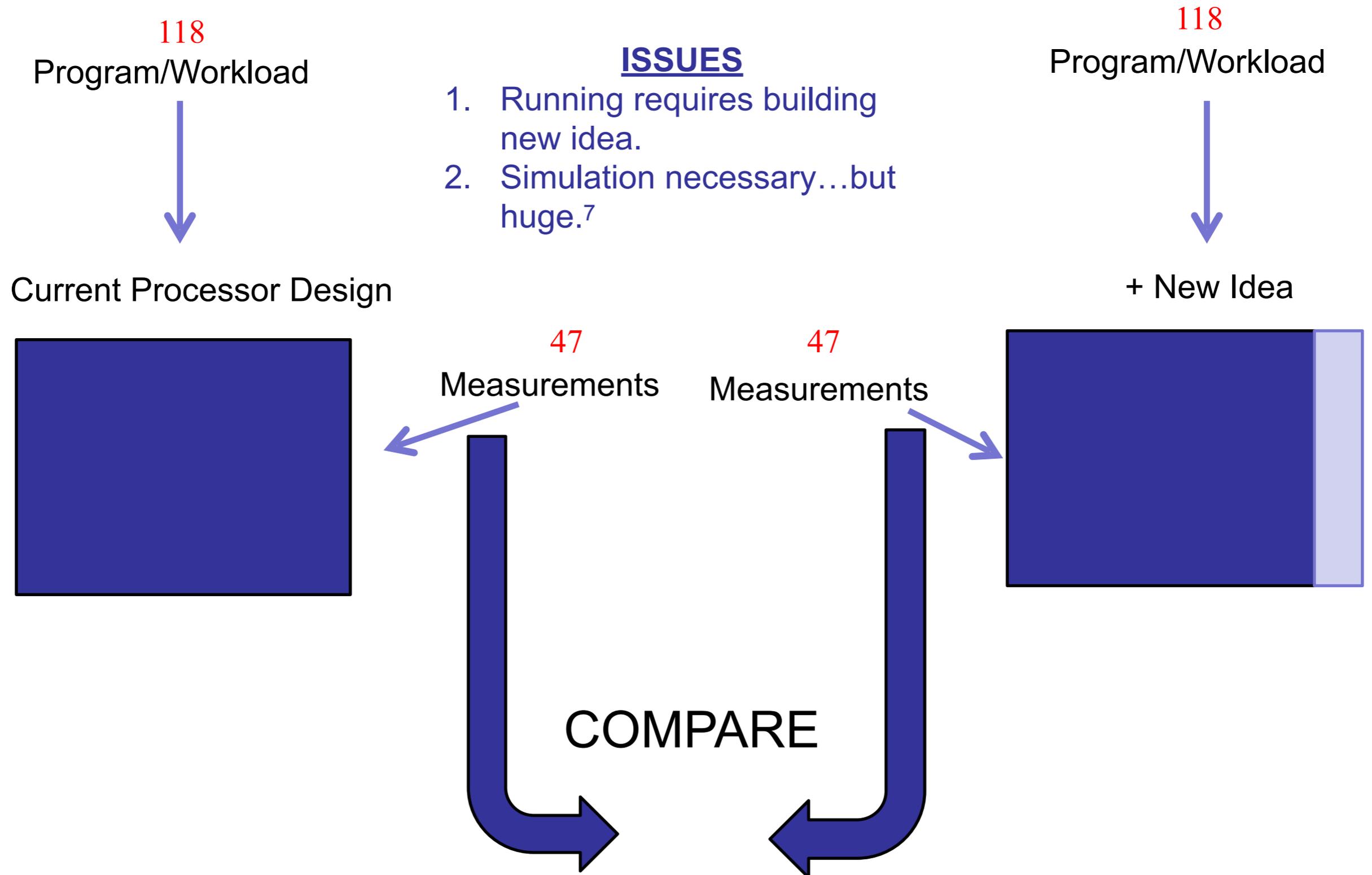


## **Research Interests**

- Education (POGIL Project, Fourth Hour)
- Workload Characterization (E-Flynn)
- Computer Architecture (FPGA Design )

# Computer Architecture

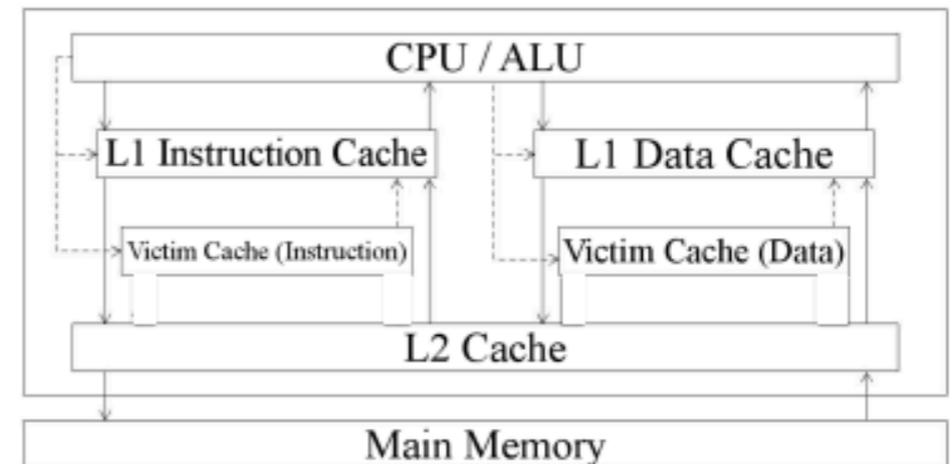
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# System Design

## Victim Caches

A victim cache is a relatively small but fully associative cache placed between the L1 (data, instruction, or both) and L2 cache layers. It captures lines evicted from L1 cache memory, thereby reducing L2 cache accesses and compensating for L1 conflict misses. Their small size in comparison to other cache layers make them worth exploring for use in both high-performance and embedded systems.



## Goals:

- Set up infrastructure for fpga design
- Make power measurements for each

# E-Flynn

	Single Data Stream	Multiple Data Streams
Single Instruction	SISD	SIMD
Multiple Instruction	MISD	MIMD

## Flynn's Taxonomy

```

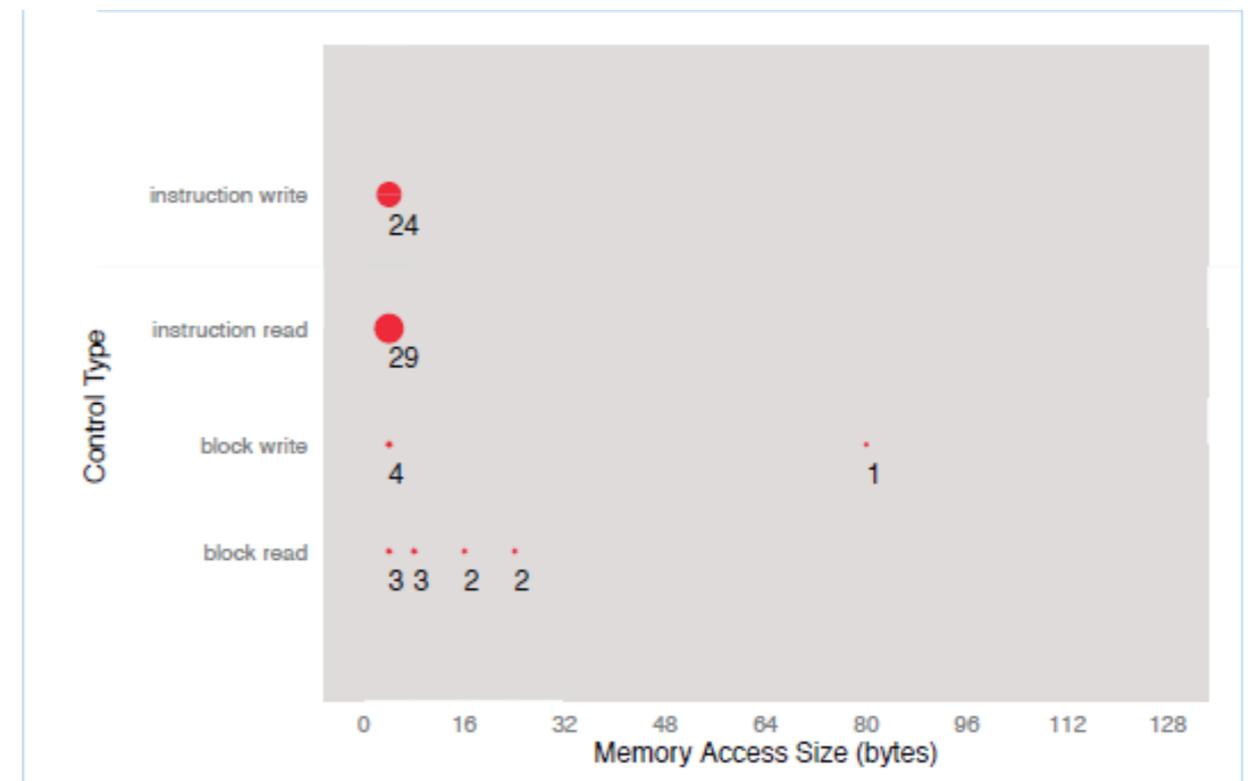
int binary_search( int nums[], int first, int last, int x) {
    while (first <= last) {
        int center = (first + last) / 2;
        if ( x > nums[center]) {
            first = center + 1;
        } else if (x < nums[center]) {
            Last = center - 1;
        } else {
            return center;
        }
    }
    return -1;
}

int main() {
    int nums[] = { 1, 4, 8, 14, 17, 19, 25, 27, 29, 48, 49, 51, 53,
57, 79};
    binary_search{nums, 0, 15, 14};
}
    
```

Figure 2: C++ code for a binary search

	2	2 <sup>2</sup>	2 <sup>3</sup>	2 <sup>4</sup>	...
Instruction					
Basic Block					
Loop/Function					
Thread					
Program					

## Expanded Flynn's Taxonomy



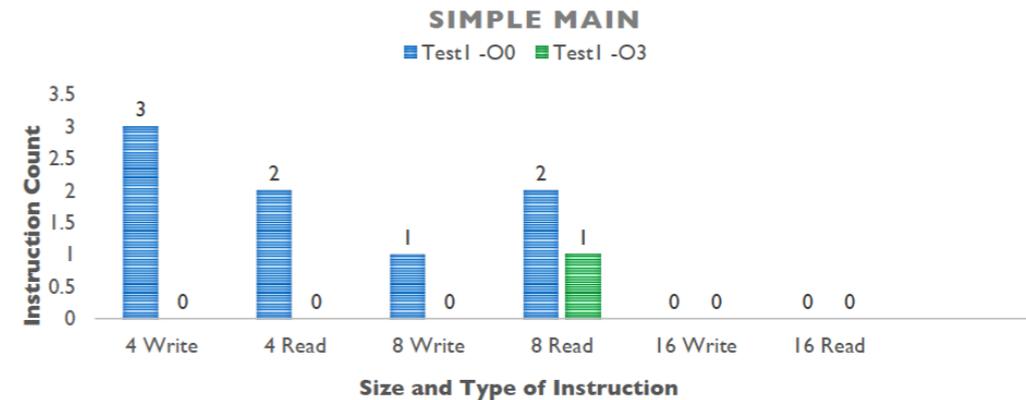
# E-Flynn at JMU

Kylie Davidson, Ryan Heick, and Mac Koslowski

## Test Algorithms and Assembly Code:

### Simple Main

```
int main (void)
{
    int x = 0;
    int y = 2;
    x = y;
    return x;
};
```

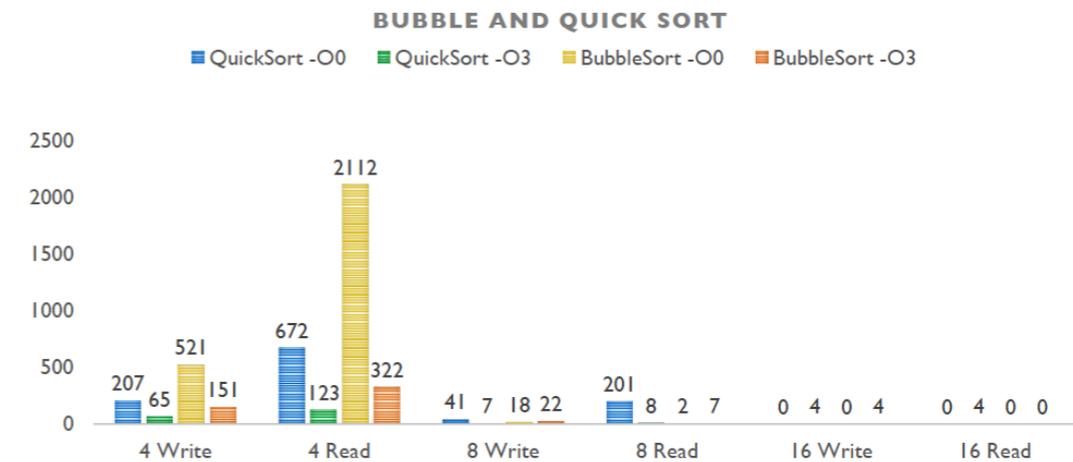


### Quick Sort

```
void quicksort(int nums[], int left, int right)
{
    int i = left;
    int j = right;
    int pivot = nums[(left+right) / 2];
    while(i <= j){
        while(nums[i] < pivot) {
            i++;
        }
        while(nums[j] > pivot) {
            j--;
        }
        if (i <= j) {
            int temp = nums[i];
            nums[i] = nums[j];
            nums[j] = temp;
            i++;
            j--;
        }
    }
    if (left < j) {
        quicksort(nums, left, j);
    }
    if (i < right) {
        quicksort(nums, i, right);
    }
}
```

### Bubble Sort

```
int main (int argc, const char* argv[])
{
    int i;
    int j;
    int temp;
    int a[] = {7,2,9,18,54,79,101,8,9,21,34,66,1,0,102,19};
    for(i = 0; i < 16; i++)
    {
        for(j = 0; j < 16; j++)
        {
            if(a[j+1] < a[j])
            {
                temp = a[j];
                a[j] = a[j+1];
                a[j+1] = temp;
            }
        }
    }
};
```



**Dr. Michael  
Lam**



# My research interests (Mike Lam)

- Program analysis (CS 430, 432)
- Systems-level software tools (CS 261)
- High-performance computing (CS 470)
- Real number representations (CS 261)



*I write software tools (primarily instrumentation-based) to analyze computer programs, with the goal of improving performance or improving accuracy.*

Current projects:

- **CRAFT and FloatSmith**

Reports precision requirements for each instruction in a program  
Create mixed-precision versions of a program (binary and source level)

- **SHVAL**

Simulates running programs with an alternate precision (e.g., double vs. single)

- **Automatic differentiation** (collaboration with LLNL)

Rigorously quantify each input's effect on each output

- **Less-Java** (new/upcoming collaboration with Dr. Stewart)

New language/compiler for introductory programming



<http://HClentist.com>

# Dr. Michael Stewart

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## Teaches:

- Intro (CS 149 and 159)
- Interaction Design
- Web Development (eventually)
- Mobile App Development (eventually)



# Human-Computer Interaction

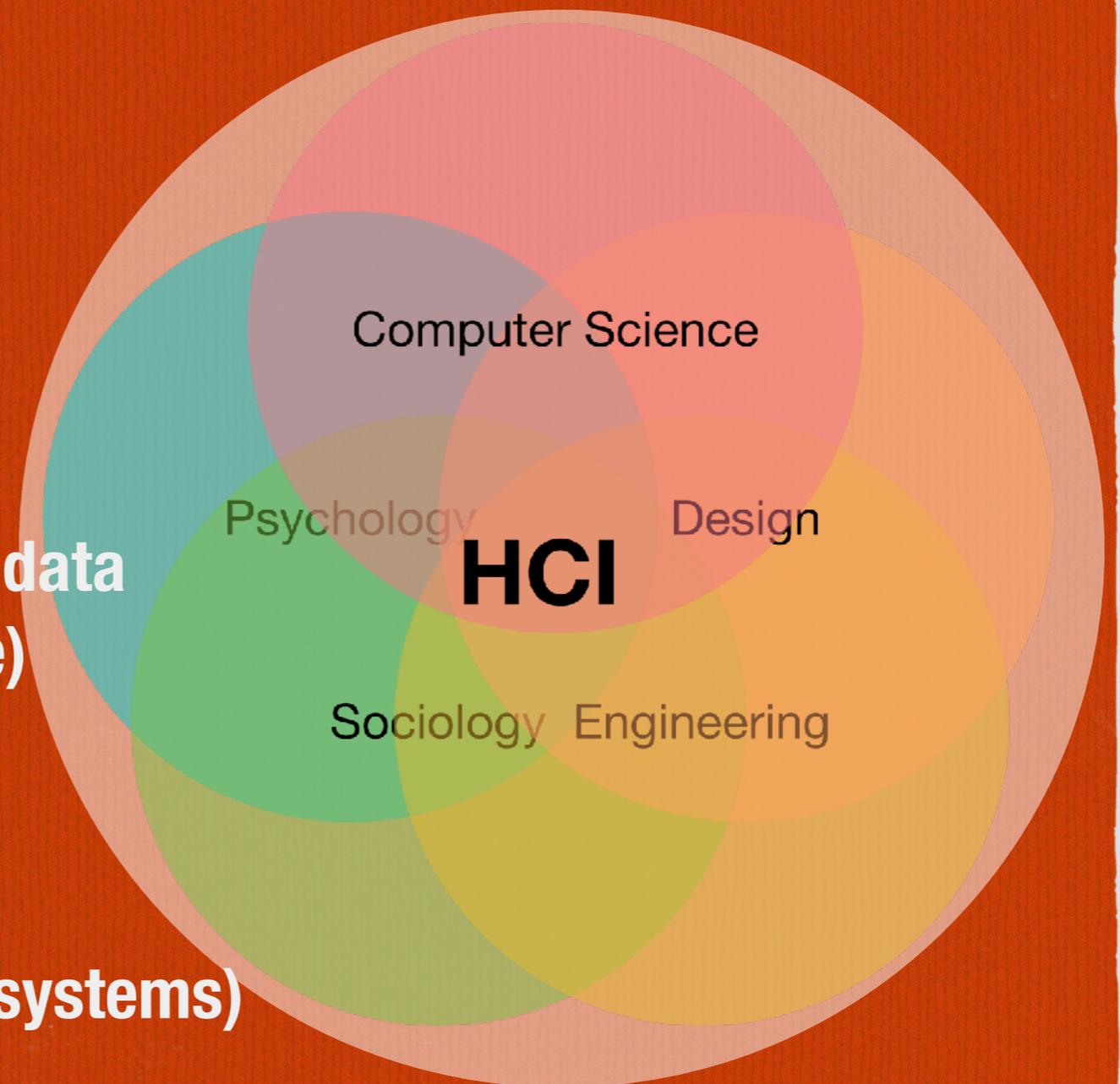
Interdisciplinary research field centered around the way people use technology (or don't) and the effects of technology use on people.

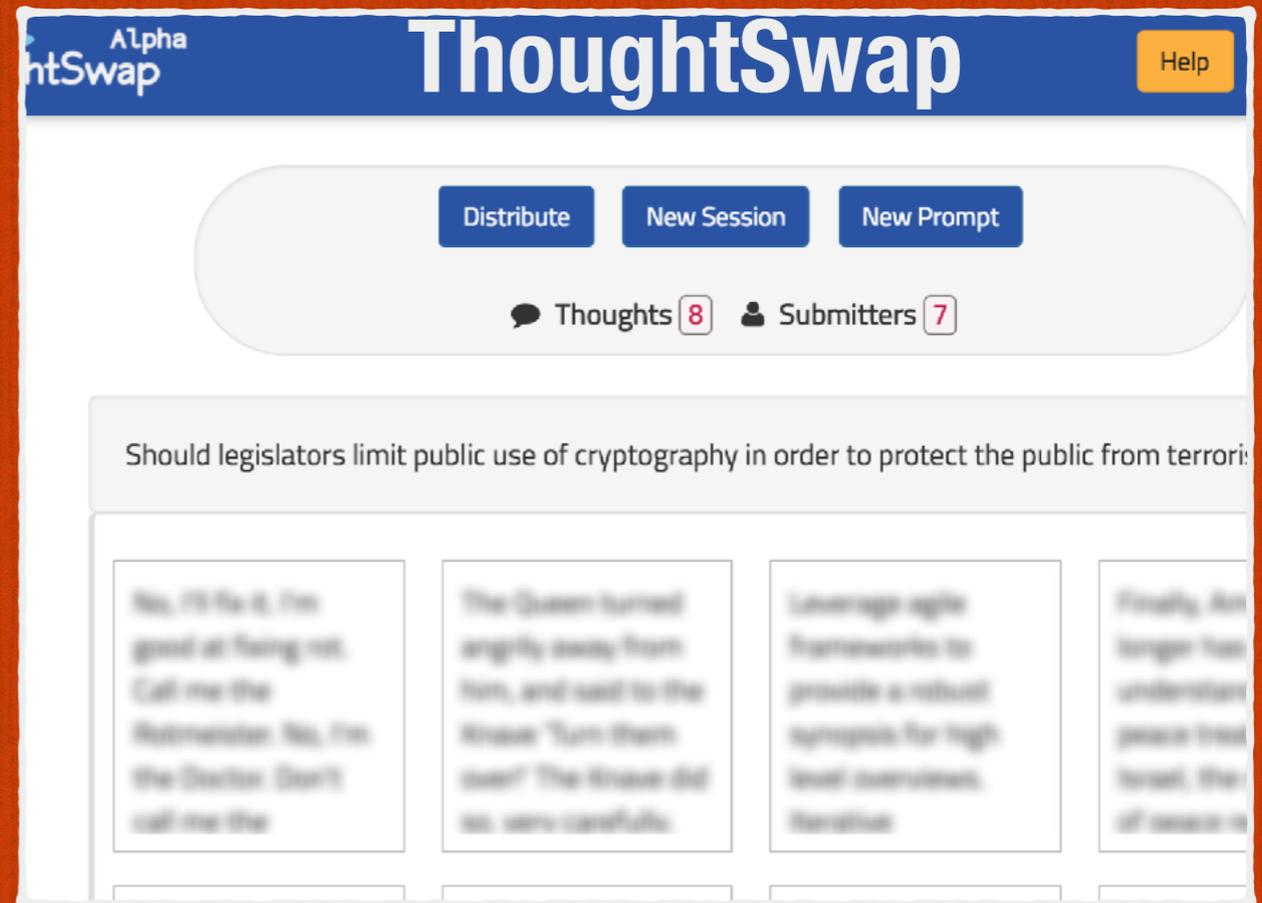
1. Gather qualitative and quantitative data about people and systems (evaluate)

2. Produce Implications for Design

3. Design

1. Evaluate (gather qualitative and quantitative data about people and systems)





# EduGit

- publication, adoption, and attribution of curricular materials
- collaboration and critique of curricular materials

# Process Oriented Guided Inquiry Learning in Introductory Computer Science



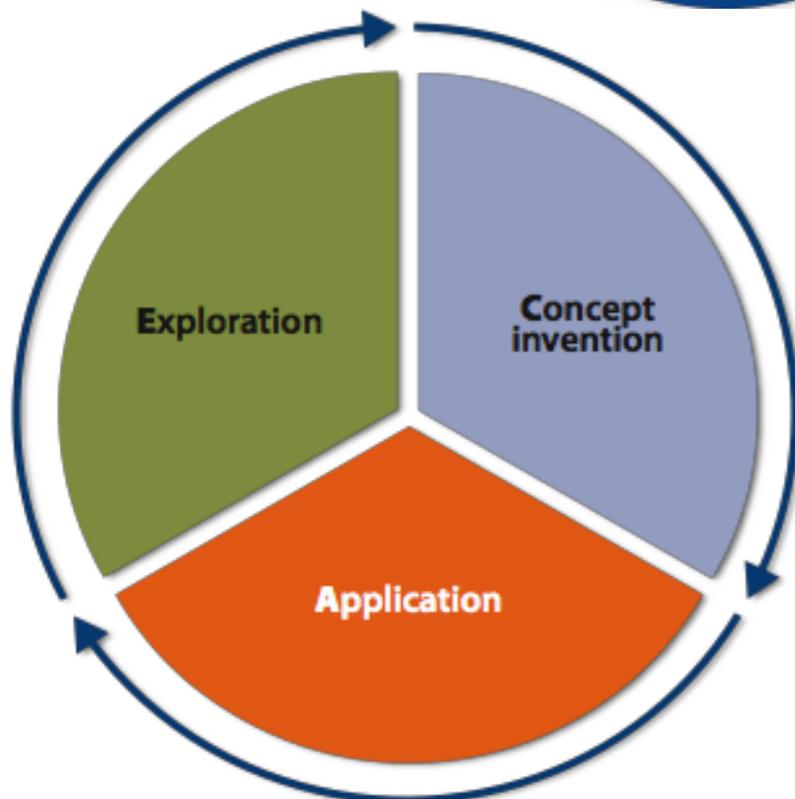
Helen Hu, Westminster College  
Clif Kussmaul, Muhlenberg College  
Chris Mayfield, James Madison University  
Aman Yadav, Michigan State University

# What is POGIL?

Process Oriented  
(cooperative learning):  
conscious commitment  
to development of  
important process skills

Guided Inquiry  
(constructivism):  
learning cycle activities

Process  
Oriented  
Guided  
Inquiry  
Learning



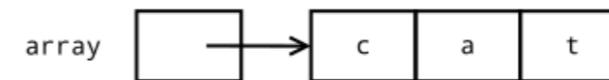
## Model 1 Character Arrays

The primitive type `char` is used to store a single character, which can be a letter, a number, or a symbol. In contrast, the reference type `String` encapsulates an array of characters.

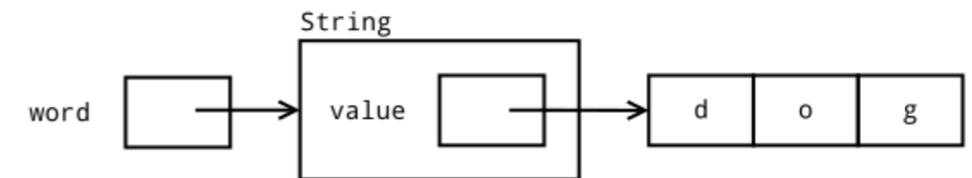
```
char letter;  
letter = 'A';
```



```
char[] array;  
array = new char[]  
    {'c', 'a', 't'};
```



```
String word;  
word = "dog";
```



Questions (15 min)

Start time: \_\_\_\_\_

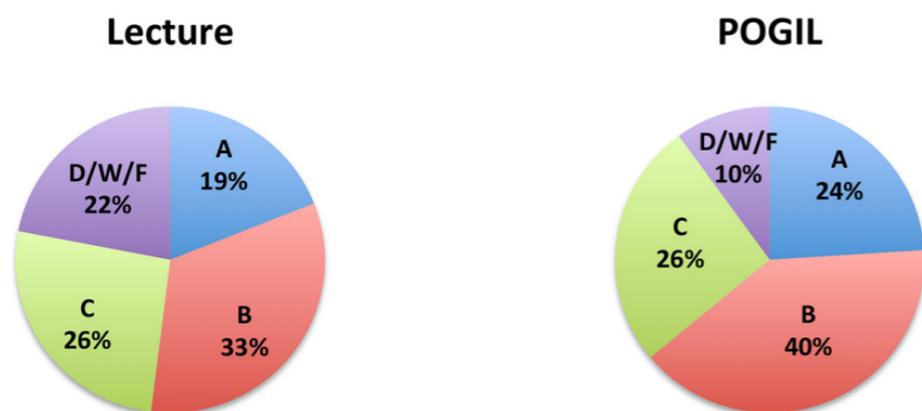
1. How is the syntax of character literals and string literals different?

2. What is the index of 'd' in the string above? What is the index of 'g'? In general, what is the index of the last character of a string?

# Related Work (in Chem Ed)

## Grade Distributions in General Chemistry

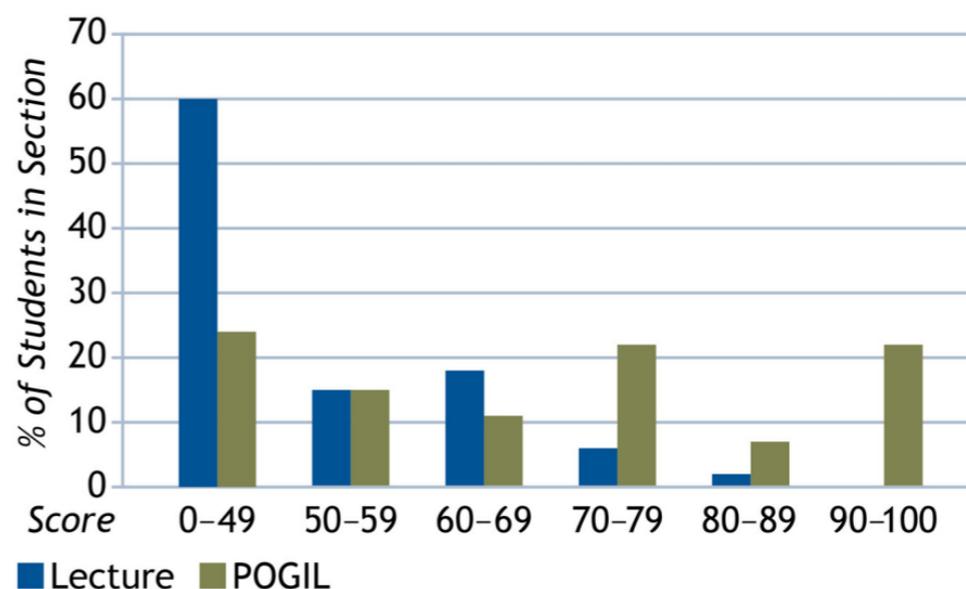
Data (n = 905) from small (~24 students) sections of three instructors using lecture approach (1990-94) prior to implementation of POGIL pedagogy (1994-98).



## Performance on Organic Chemistry 2 Unannounced First Day Pre-Quiz

All students passed Organic Chemistry 1 at this institution during the previous semester

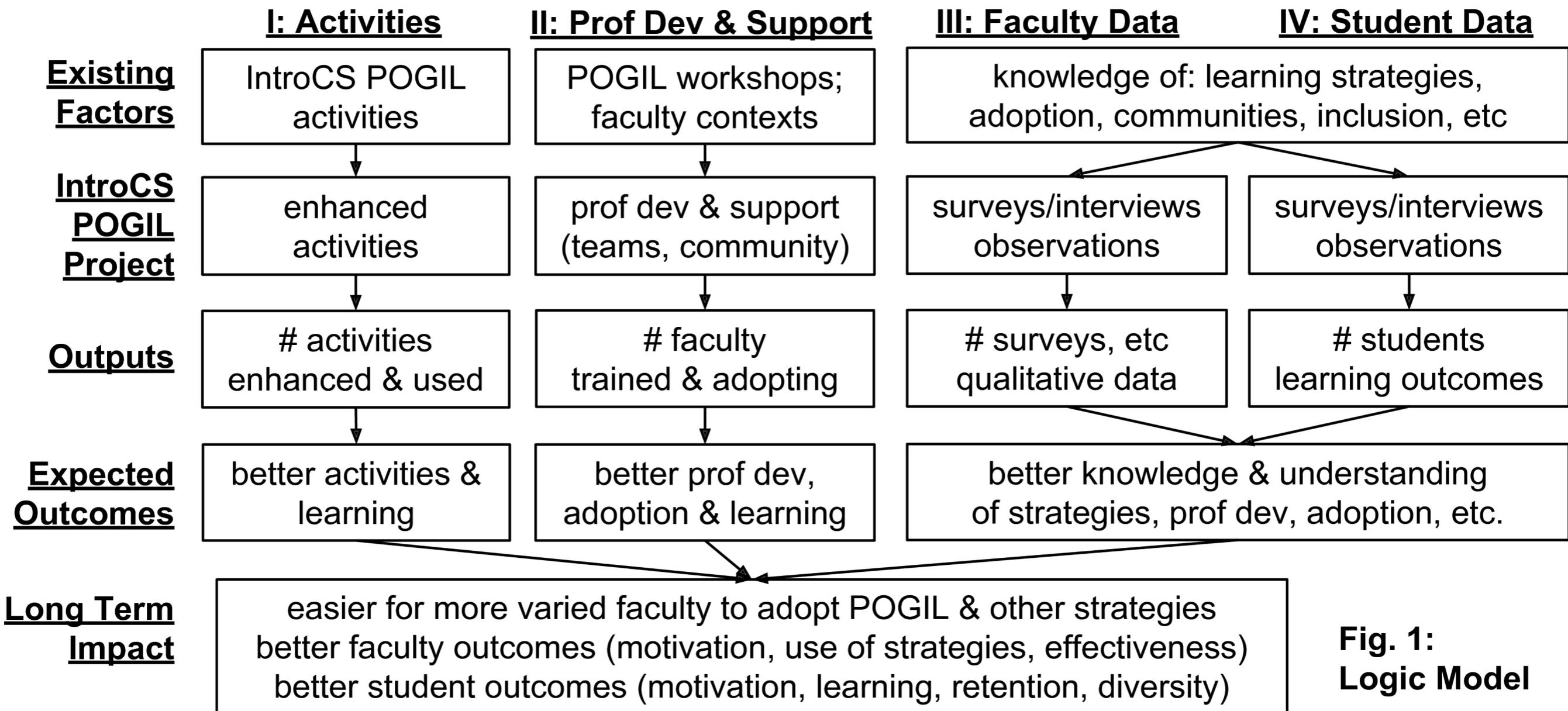
All sections of Organic Chemistry 1 had more than 150 students.



Ruder, S.M., & Hunnicutt, S.S. (2008). POGIL in Chemistry Courses at a Large Urban University: A Case Study. In R.S. Moog, & J.N. Spencer (Eds.), *Process-Oriented Guided Inquiry Learning: ACS Symposium Series 994* (pp. 133-147). Washington, D.C.: American Chemical Society.

Farrell, J.J., Moog, R.S., & Spencer, J.N. (1999). A Guided Inquiry Chemistry Course. *Journal of Chemical Education*, 76, 570-574.

# 5-Year Project in CS



**Fig. 1:**  
**Logic Model**

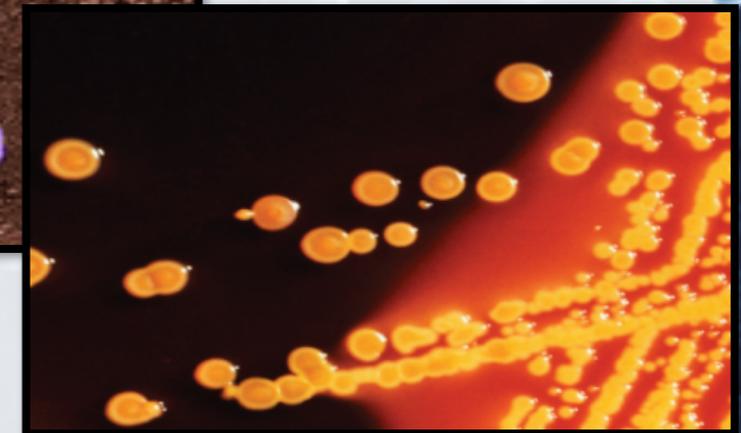
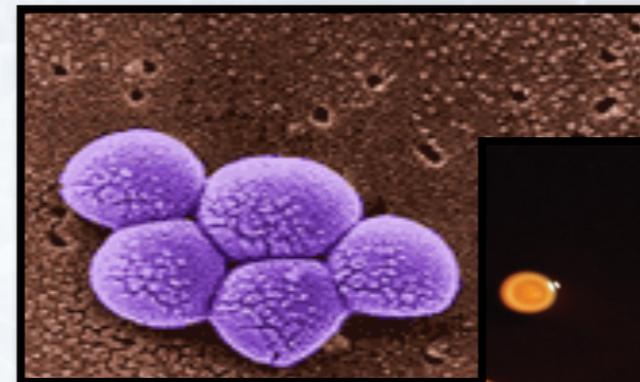
**Dr. Kevin  
Molloy**



# Computational Modeling of AntiMicrobial Peptides (AMPs) Characteristics

## Motivation

- Reports of antibiotic resistance have *increased*
- The U.S. Center for disease control reports over 2 million infections and 23,000 deaths each year due to antibiotic-resistant bacteria and fungi in the US
- *Despite the urgency and the need, a slowdown is occurring in delivering new antibiotics to market [1]*



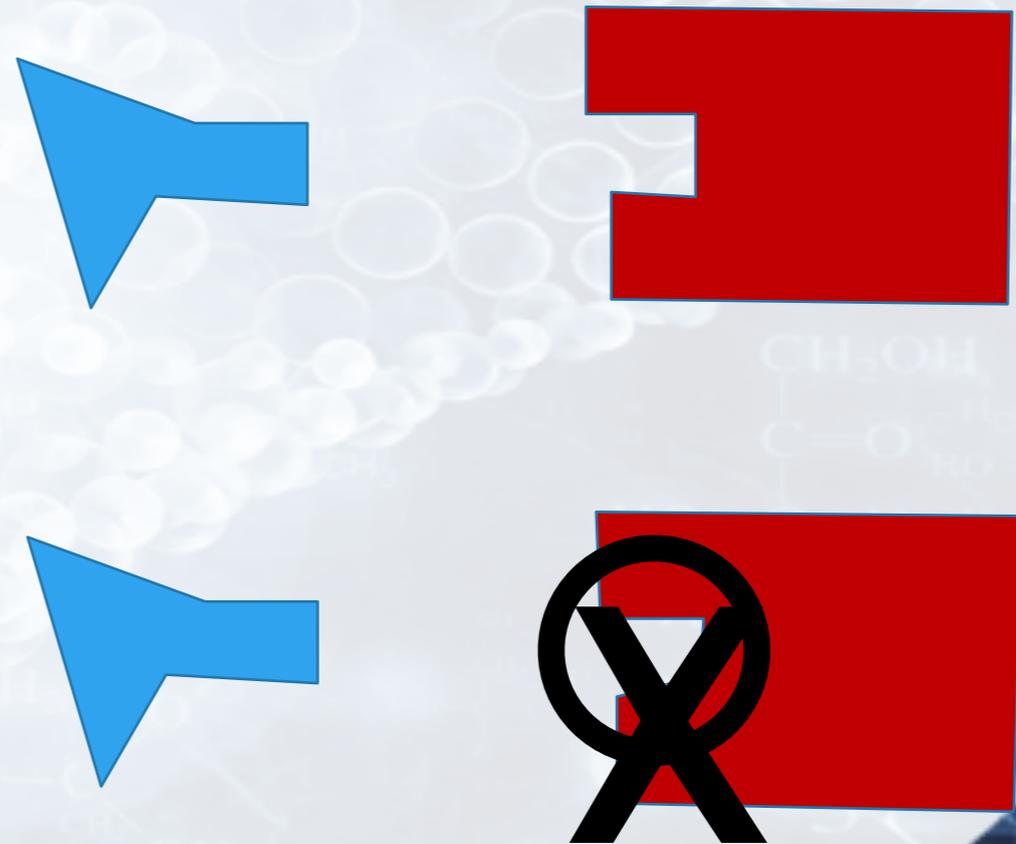
Methicillin-resistant *Staphylococcus aureus* (left)  
Carbapenem-resistant *Enterobacteriaceae* (right)

Slide adapted from D. Veltri - National Institute of Allergy and Infectious Diseases

[1] CDC <https://www.cdc.gov/drugresistance/about.html>

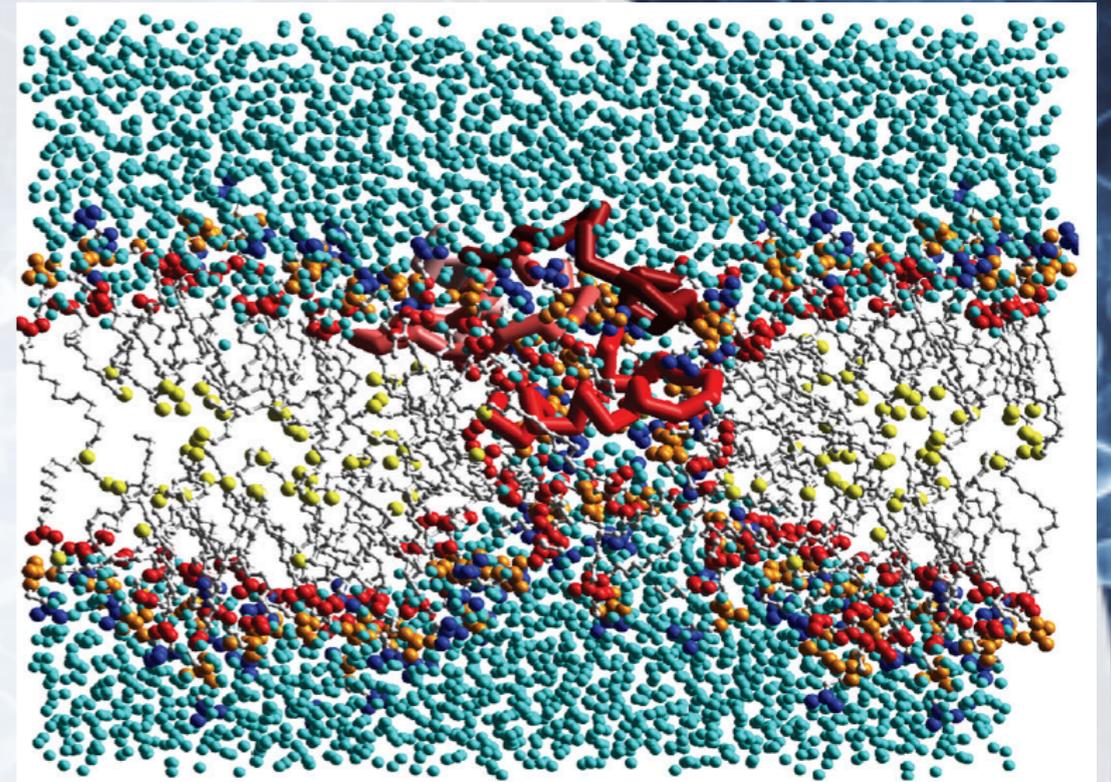
# Cycle of Antibiotic Resistance

- Bacterial proteins have a variety of 3D structures and functions
- Many antibiotics (blue) work by "docking" or interfacing with the protein (red) and blocking its natural function, resulting in the death of the bacteria
- Chance mutations in the DNA that codes for a protein can alter its shape and inhibit docking, allowing the bacteria to be "resistant" to the antibiotic
- A new antibiotic is now needed and the cycle repeats



# AMPs

**Antimicrobial Peptides (AMPs)** kill bacteria using mechanisms that are not as sensitive to the shape of specific proteins. They choose more *general* targets that are harder to be stopped by a few chance mutations and thus can be harder for certain species of bacteria to “resist”



**Research area:** Develop algorithms to simulate AMP behavior so that we can better characterize:

- properties of AMPs that make them effective
- determine which AMP is best suited to kill a specific bacterial strains
- **long term:** How to adapt (design) AMPs to target specific strain

The MD photo taken from Wimley, Describing the Mechanism of Antimicrobial Peptide Action with Interfacial Activity Model (2010).

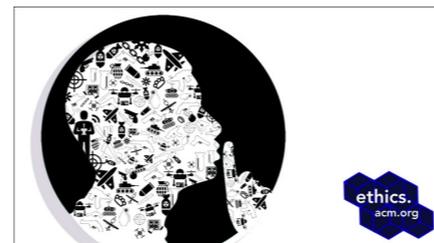


**Dr. Michael  
Kirkpatrick**

# Computing Ethics & Society



ACM Code of Ethics and Professional Conduct



## The Code

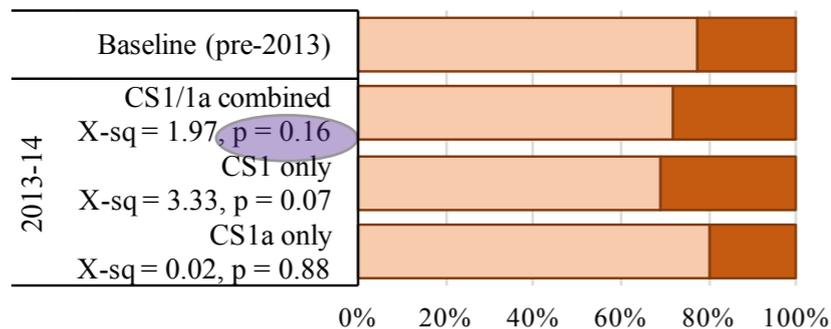
ACM Code of Ethics and Professional Conduct

### Preamble

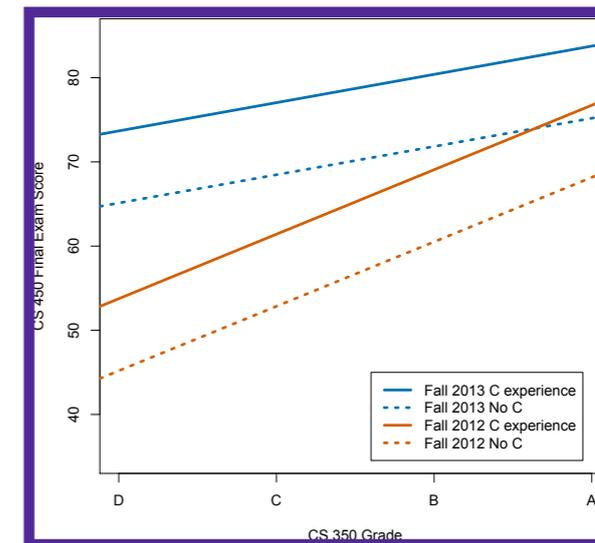
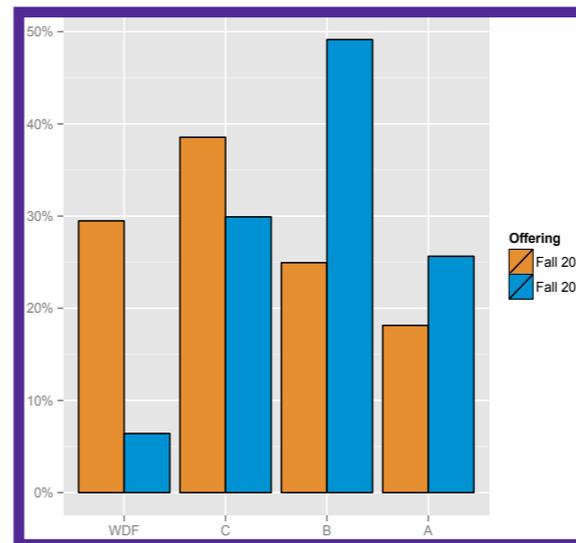
Computing professionals' actions change the world. To act responsibly, they should reflect upon the wider impacts of their work, consistently supporting the public good. The ACM Code of Ethics and Professional Conduct ("the Code") expresses the conscience of the profession.



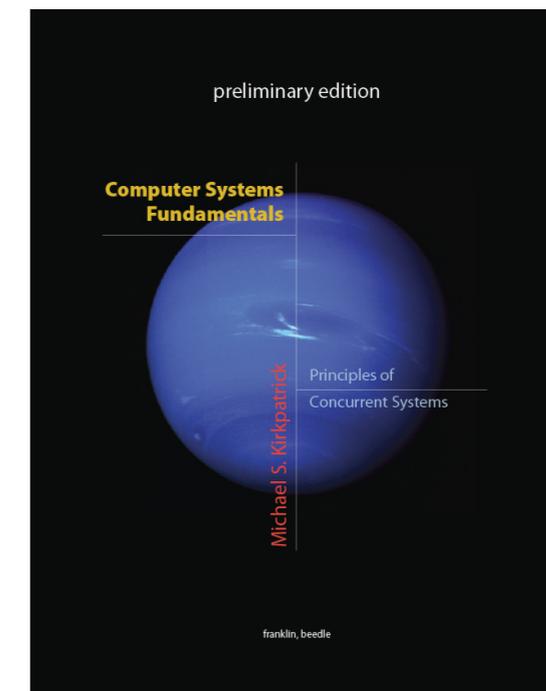
# Empirical CS Education



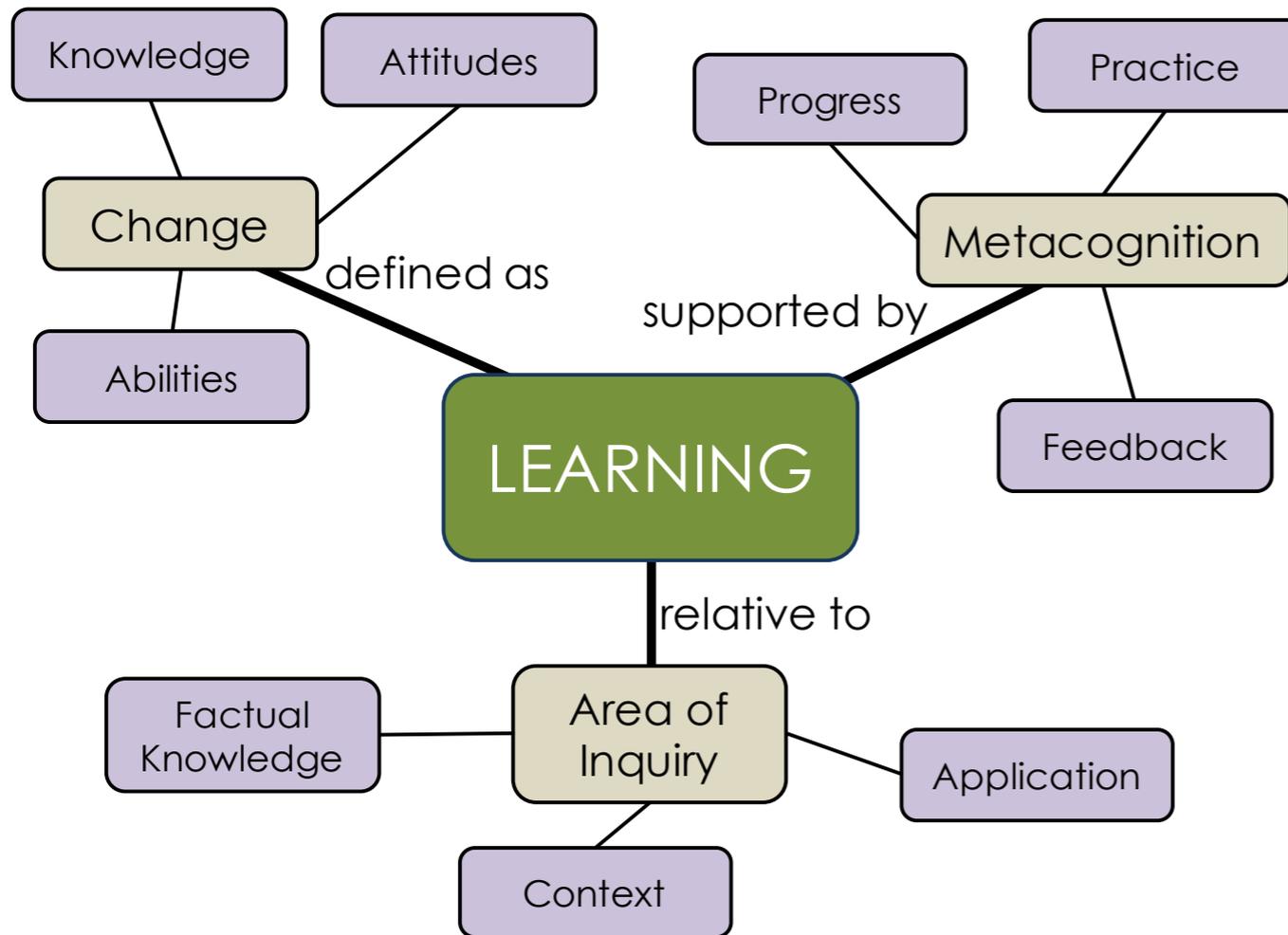
CS2 Grade				
Factor	Est.	SE	t value	Pr(> t )
(Intercept)	1.187	0.234	5.079	< 1e-06 ***
CS1.5 Grade	0.512	0.075	6.788	< 2e-10 ***
Residual standard error: 0.723 on 177 degrees of freedom				
Multiple R-squared: 0.2066, Adjusted R-squared: 0.2021				
F-statistic: 46.08 on 1 and 177 DF, p-value: 1.651e-10				



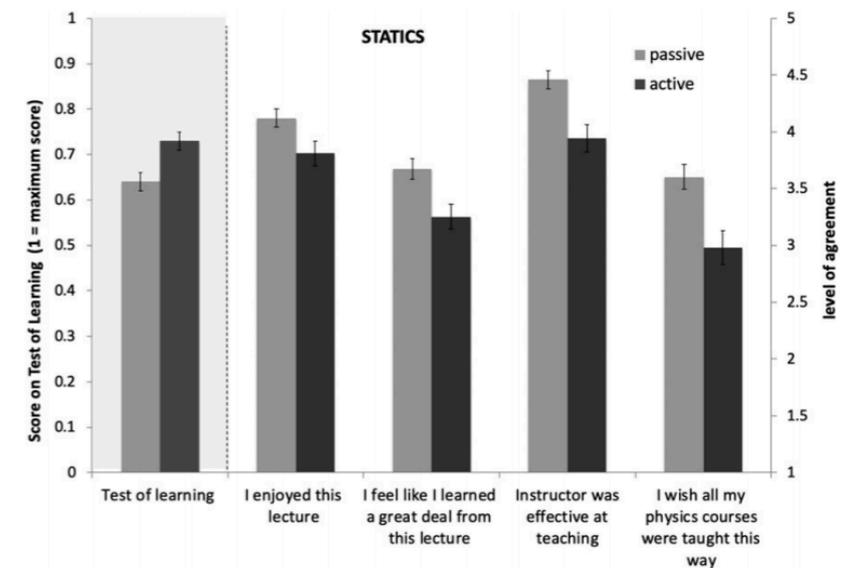
Greater learning, but difficult	Correct answers emerged from discussion	Mixed feelings on making projects collaborative
"[I]t's <u>easier to ask</u> your peers that are in your immediate group if you don't understand something."	"Even if everyone didn't know the answer exactly, like <u>when we talk about it we somehow come up with an answer.</u> "	"I mean as programmers <u>we're gonna be working on teams</u> and developing software programs."
"I would say it was harder to do things out of class, but in class was a lot more <u>valuable time.</u> "	"I made a joke along the lines of <u>as a group we work really well together</u> , but as an individual entity we all suck."	"I think there are others that might use that as a <u>way to cruise.</u> "



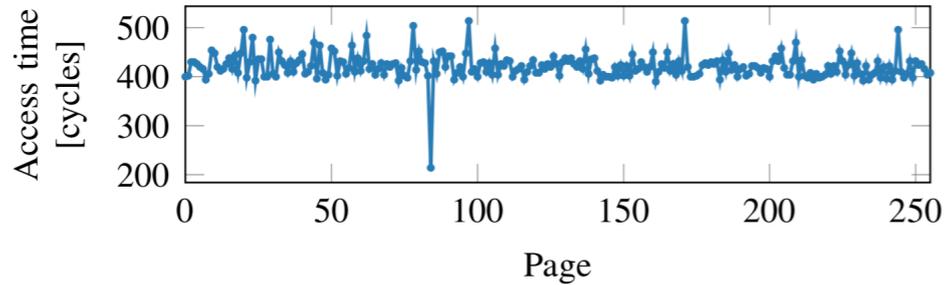
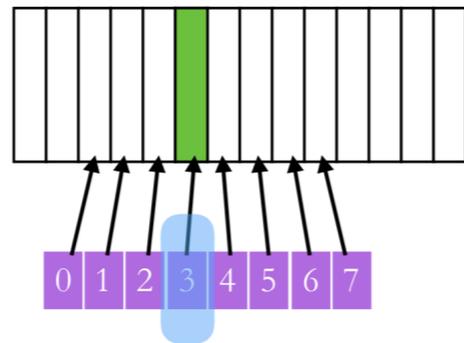
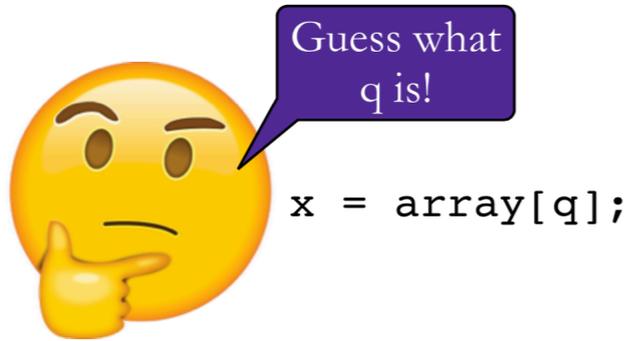
# Teaching & Learning



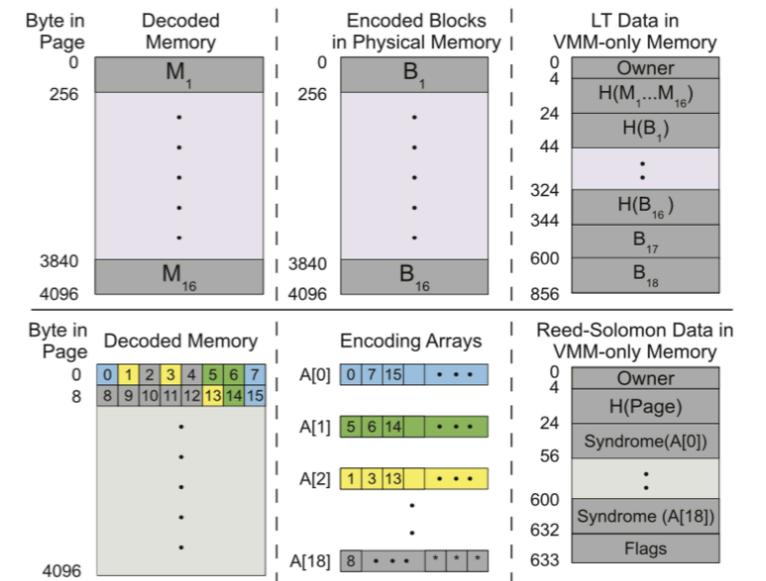
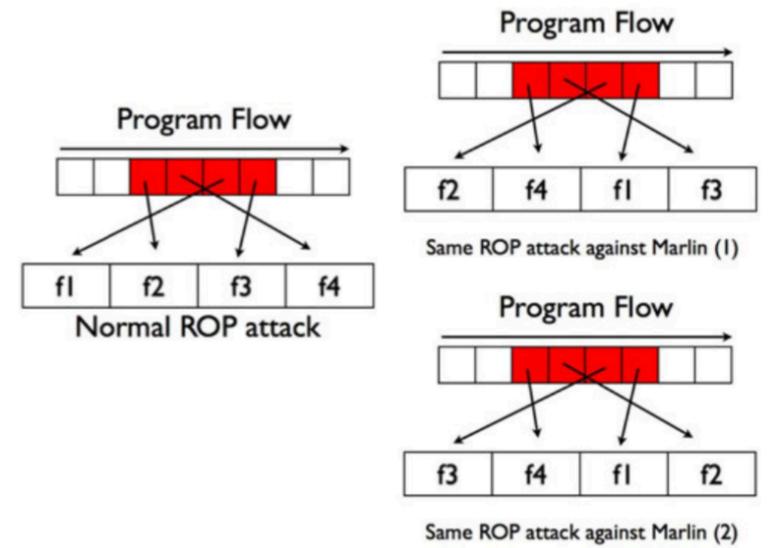
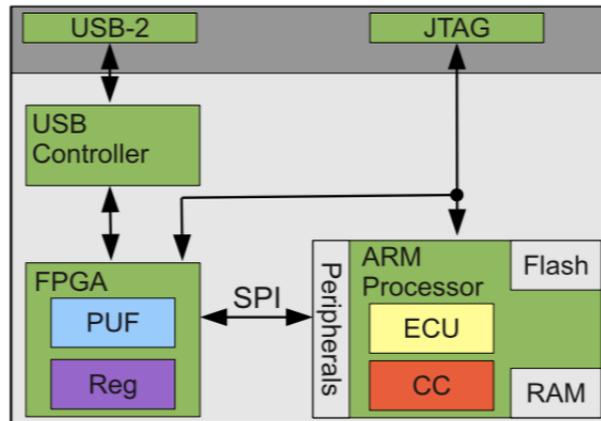
Retrieval Practice  
 Interleaving  
 Spacing Effect  
 Elaborative Encoding



# Systems Security



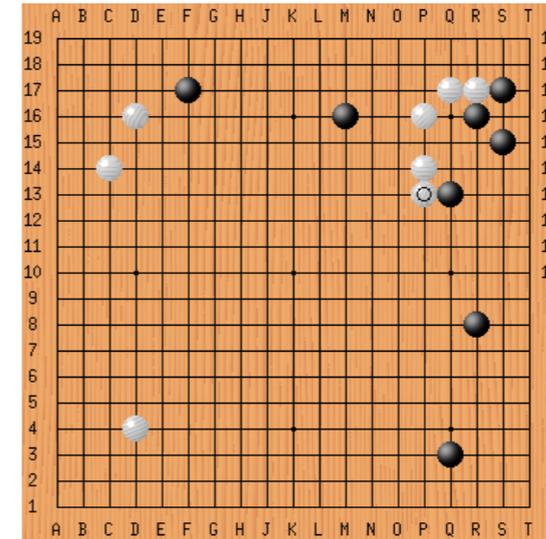
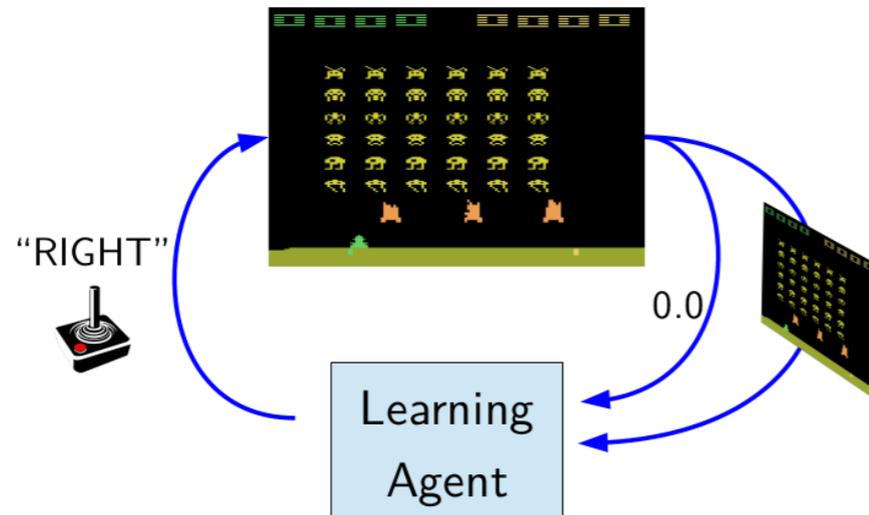
```
for (i = 0; i < 8; i++) {
    start_timer();
    y = array[i];
    stop_timer();
}
```



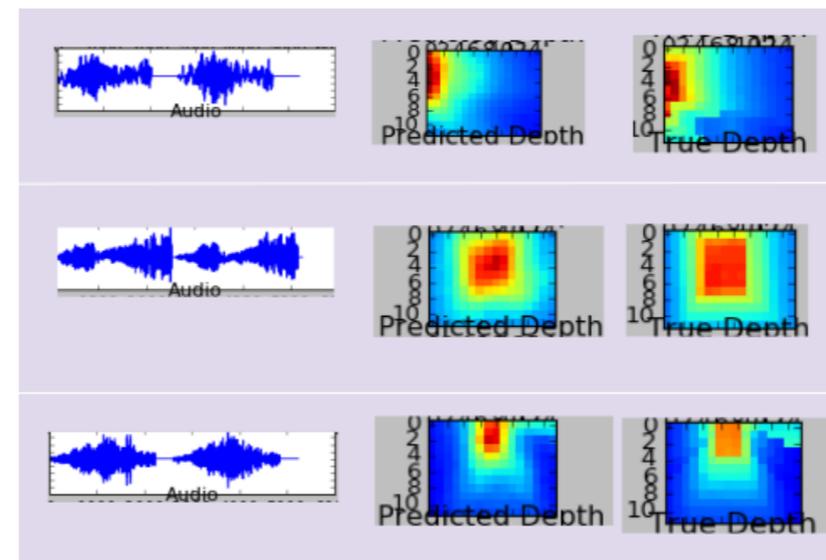
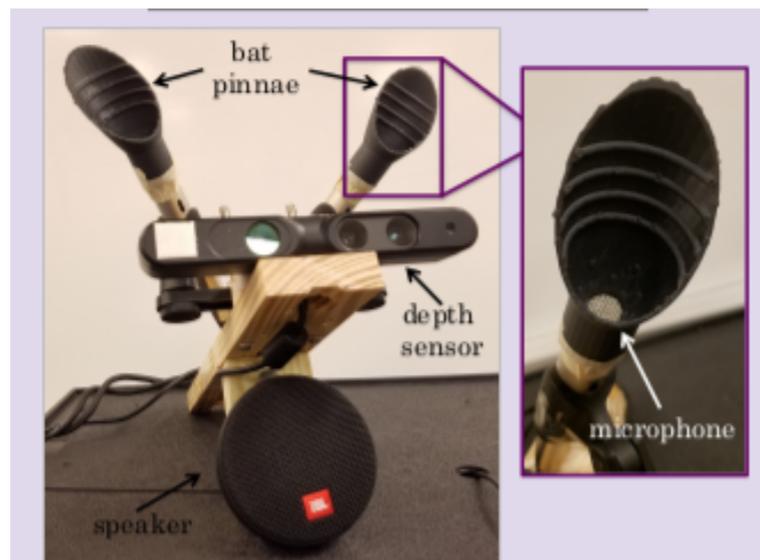
# Dr. Nathan Sprague



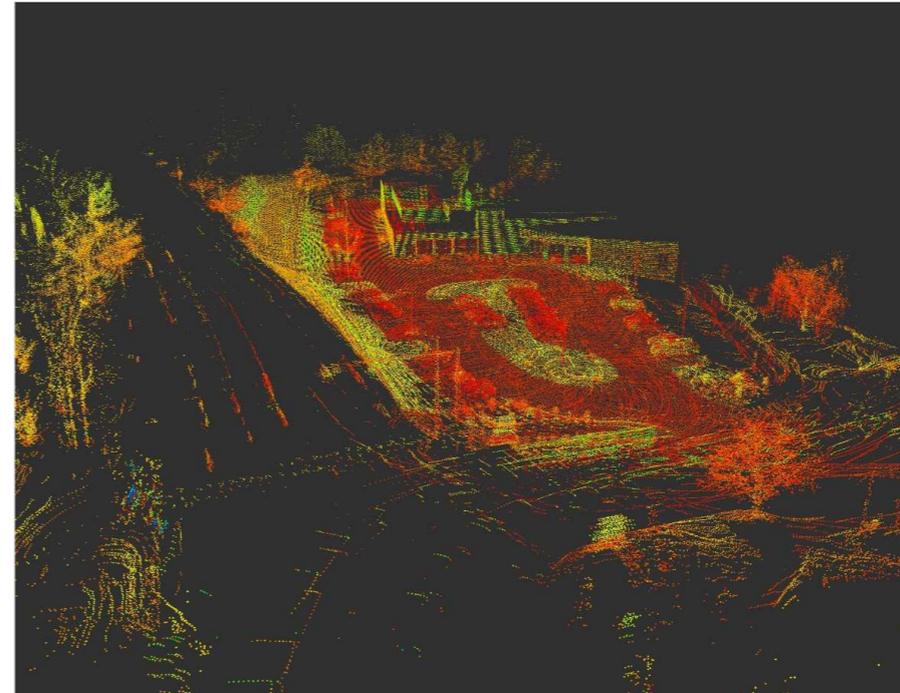
# Deep Learning For Games



# Artificial Echolocation



# Autonomous Vehicles



# Malware Identification

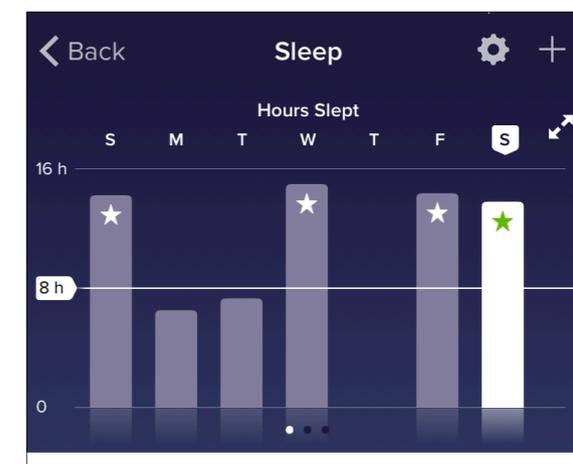
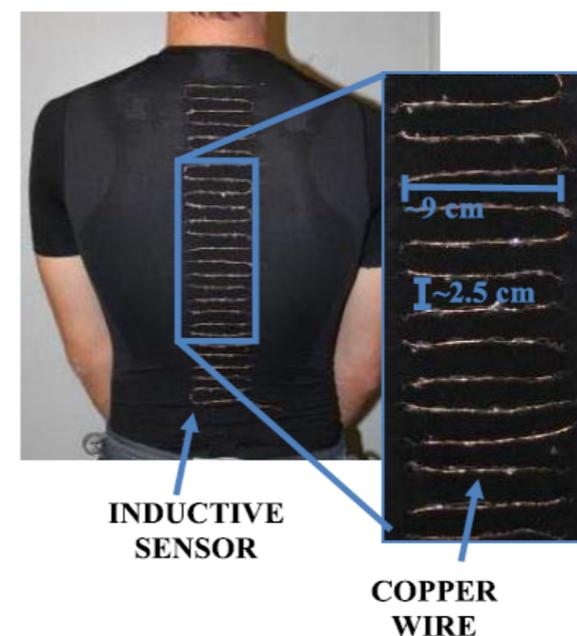
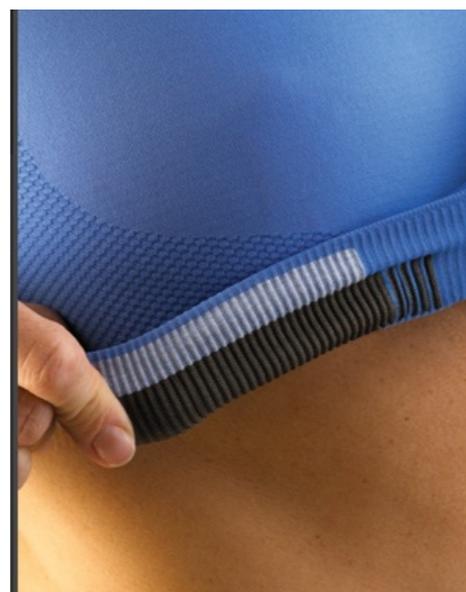
????????

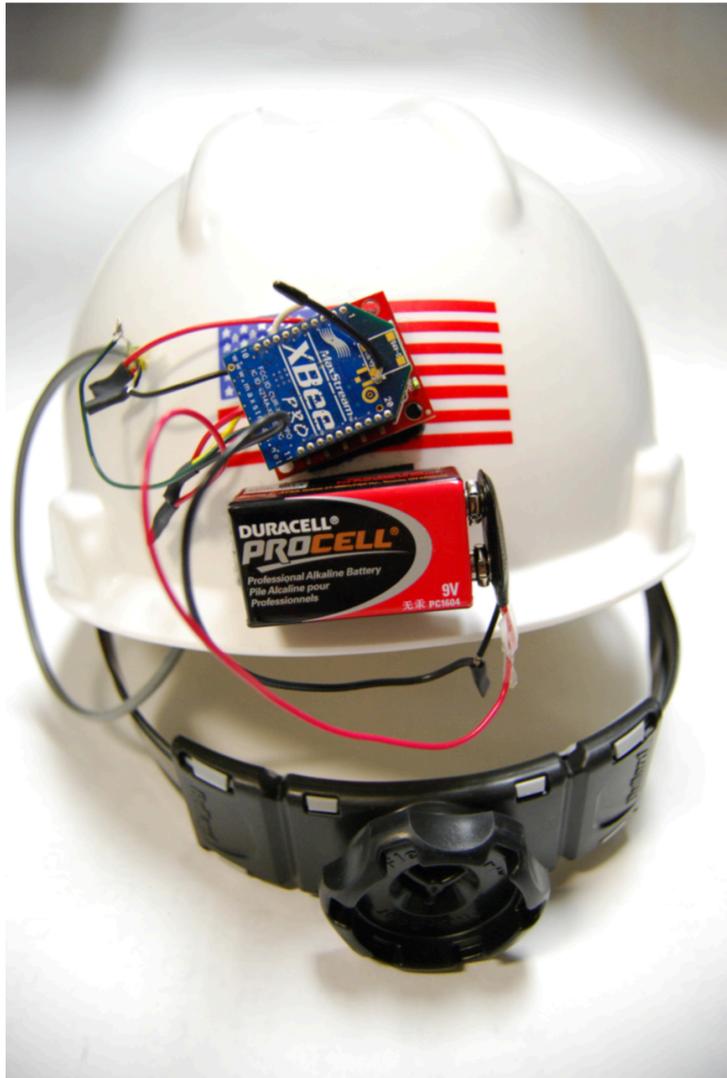


**Dr. Jason  
Forsyth**

# Wearable Computing for Health and Wellness

- Instead of going to the doctor, bring the doctor with you.
- Automatic monitoring of heart rate, blood ox, respiration rate, sleep patterns
- Analysis of walking, gait, posture to detect falls or recover from injury

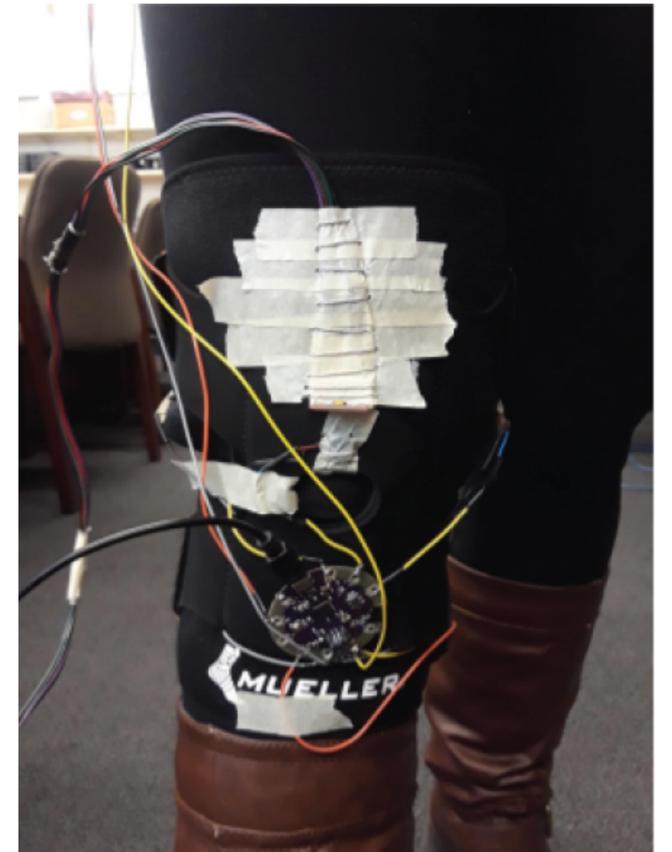




**Carbon Monoxide  
Detection**

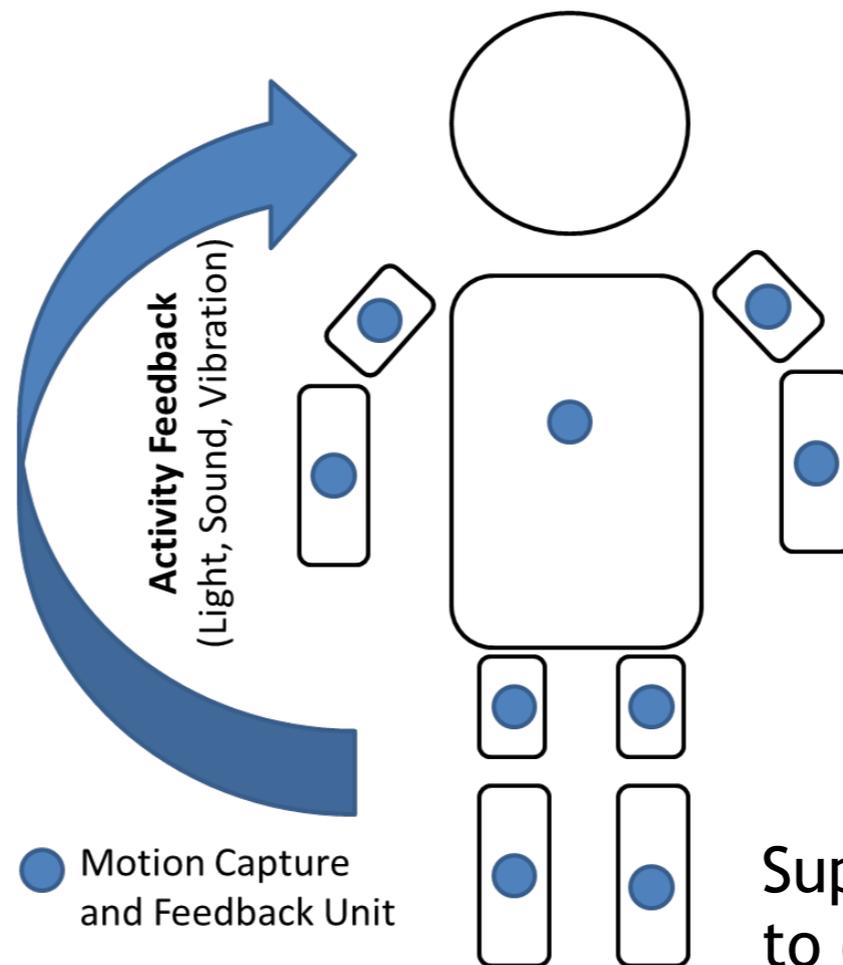


**Road-side Warning**

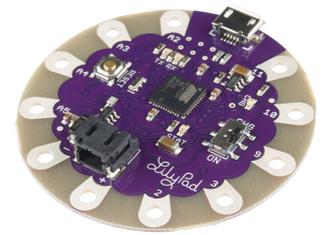


**Exercise Feedback**

# Proposed Solution: System



9-axis IMU



LilyPad

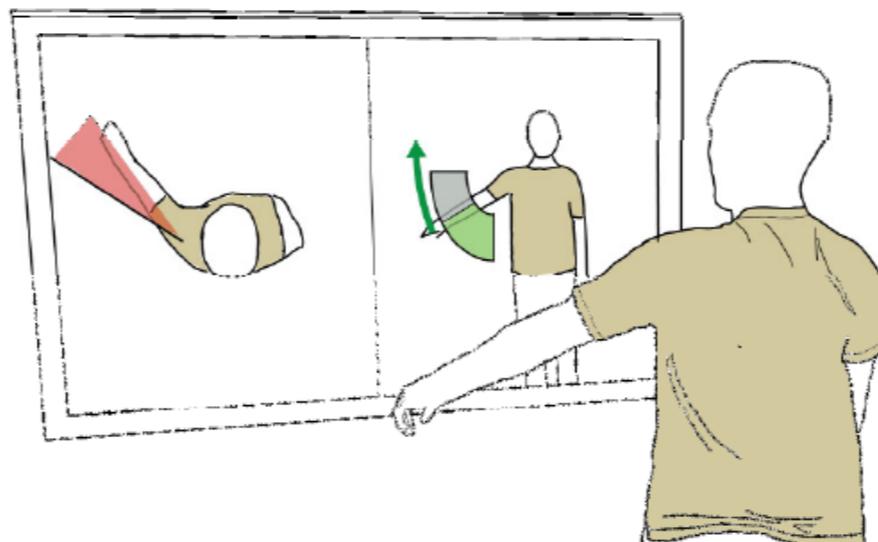
Clinical Information  
(Range of Motion, Duration)



Supports patient *adherence* to exercise regime by increasing *self-efficacy*.



Machine Learning



HCI: Patient Feedback



HCI: Physician Feedback



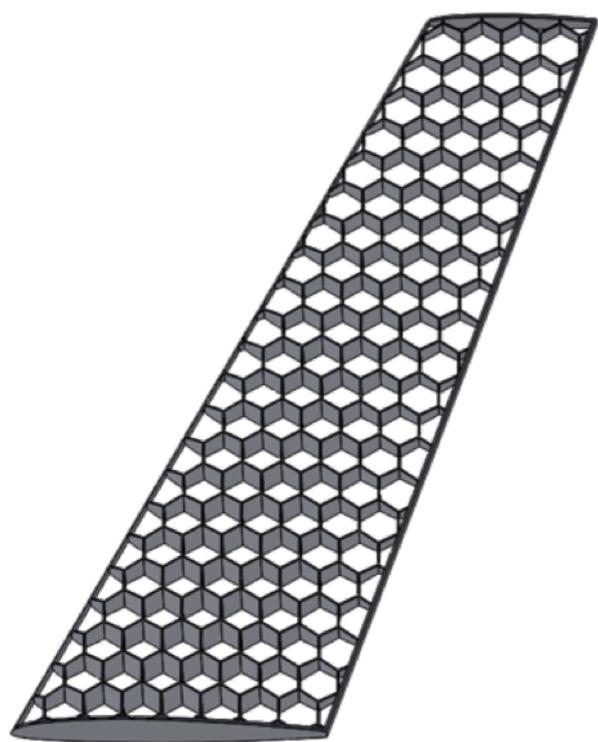
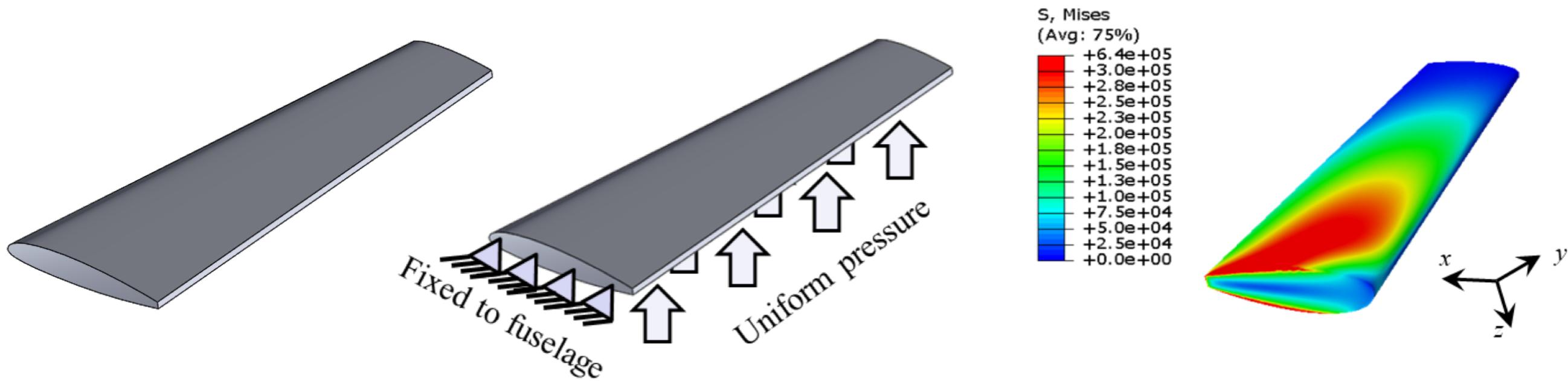
**Dr. John Bowers**



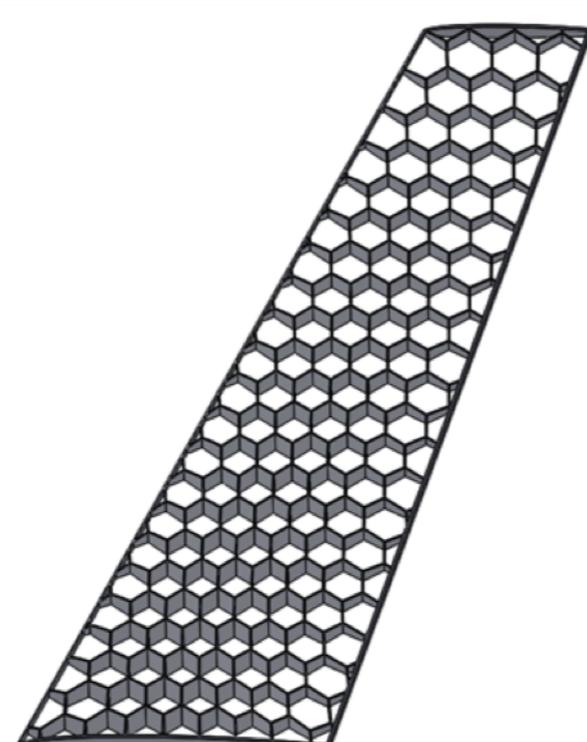


Not your math professors 3D printer

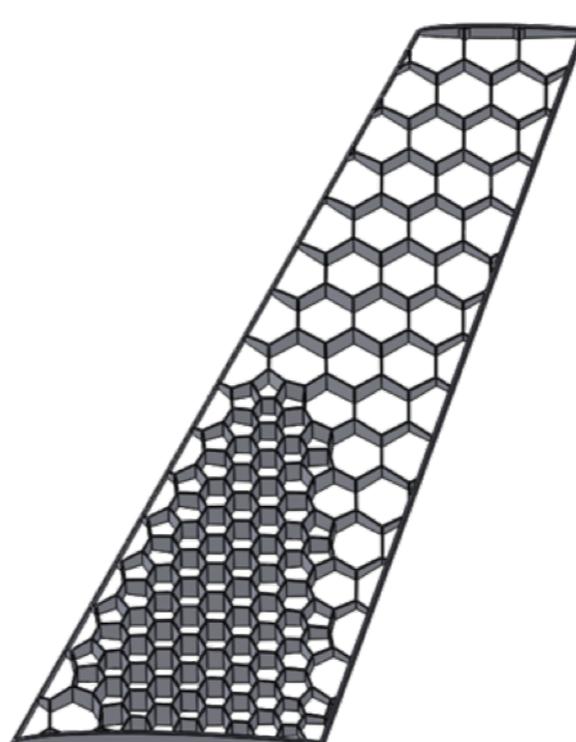




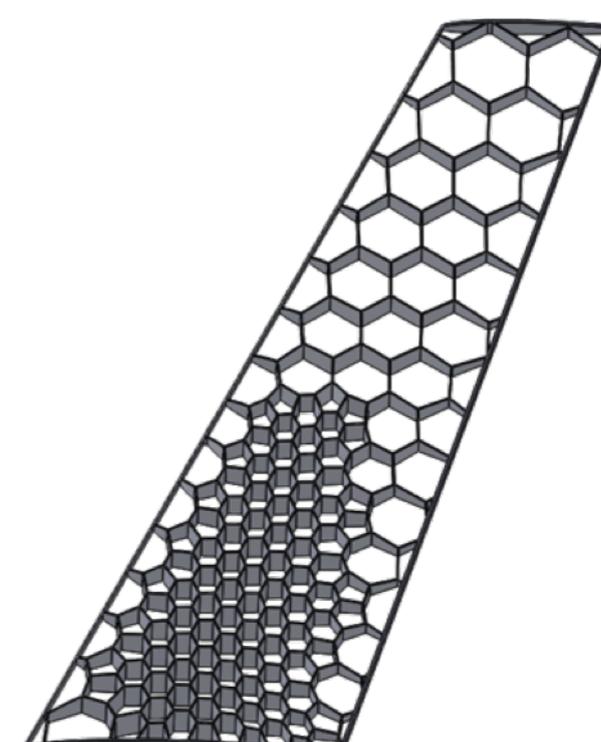
Uniform infill



Iterative circle packing



Sectioning



Iterative + Sectioning

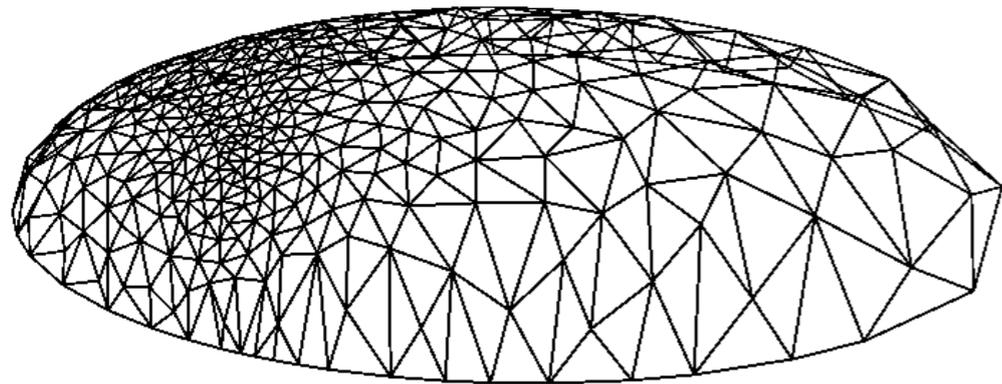
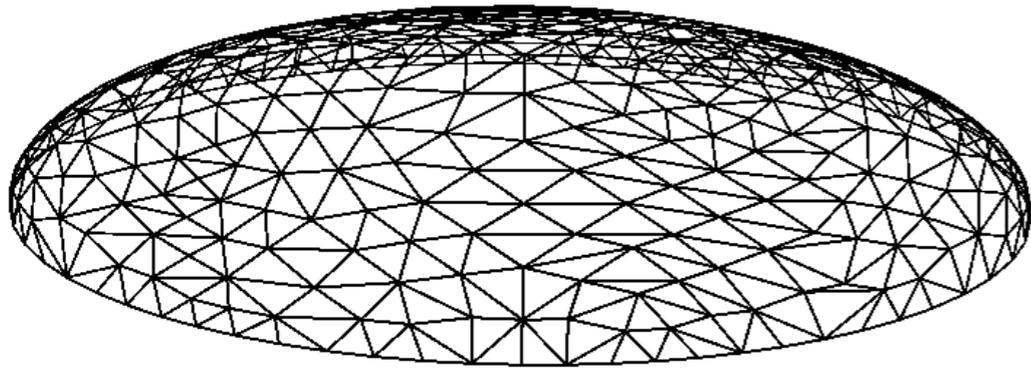
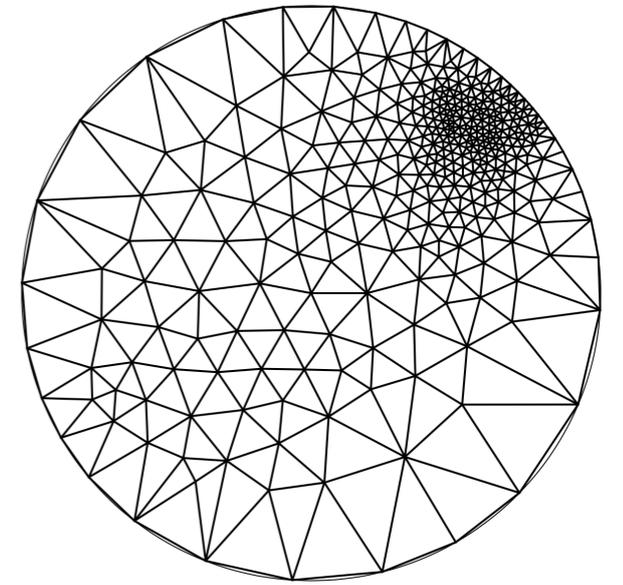
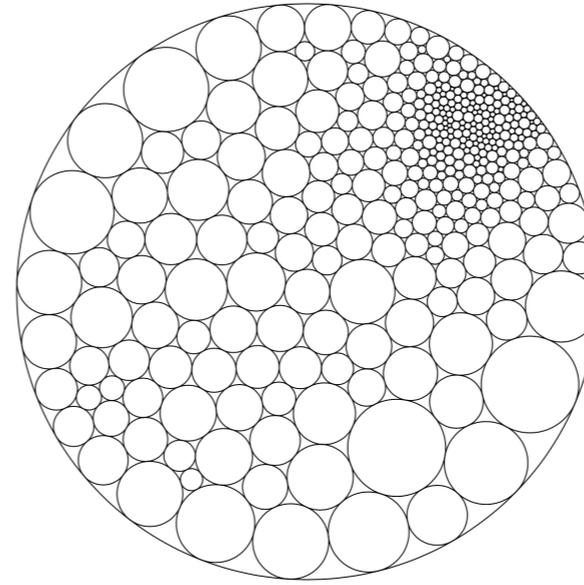
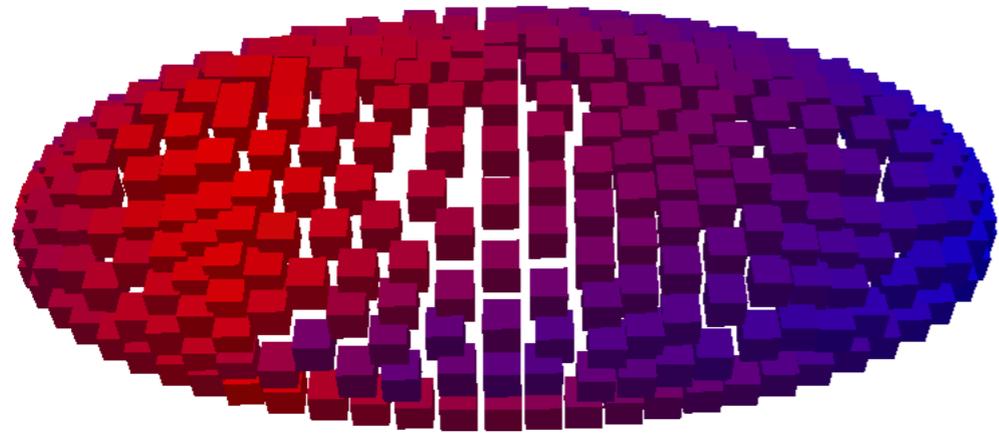


OAK RIDGE NATIONAL LABORATORY  
MANUFACTURING DEMONSTRATION FACILITY

### Large-Scale Polymer Additive Manufacturing

**Breakthroughs**

- Development of low-cost precursor materials
- Digitally manufactured parts from high-temp thermoplastics, capable of withstanding industrial conditions
- Sustainable, bio-derived materials: PLA with 30% bamboo or 20% flax

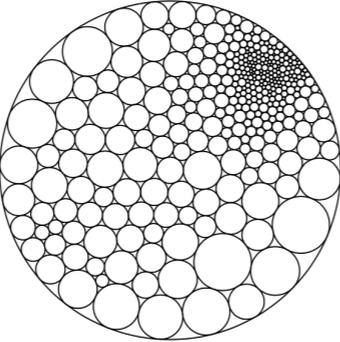


**Next: ???**

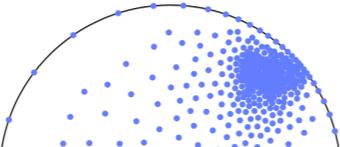
jupyter Field Based Remeshing (unsaved changes) Logout

File Edit View Insert Cell Kernel Widgets Help Not Trusted Python 3

```
In [26]: # Run this to view the circle packing
viewer = PoincareDiskViewer(300, 300)
viewer.addAll(packing.verts)
viewer.show()
```



```
In [27]: # Run this to view the circle centers
viewer = PoincareDiskViewer(300, 300)
viewer.addAll([v.data.center.coord.toPointOP2() for v in packing.verts])
viewer.show()
```



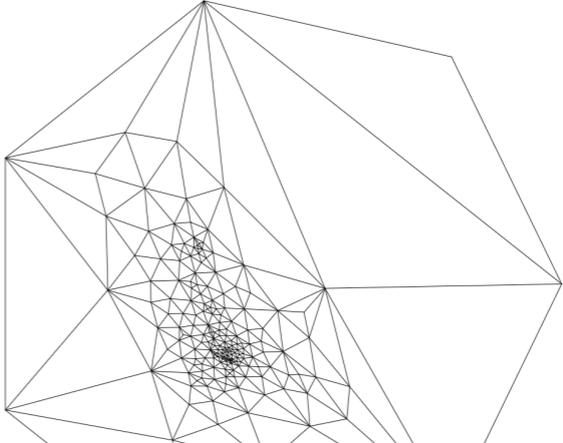
jupyter Tutte\_Embeddings (unsaved changes) Logout

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

```
viewer = TutteEmbedderSketch()
#viewer.addAll([v.data for v in poly.verts])
segments = [SegmentE2(e.aDart.origin.data, e.aDart.twin.origin.data) for e
viewer.addAll(segments)

points = [v.data for v in tutteGraph.verts]
#viewer.addAll(points)

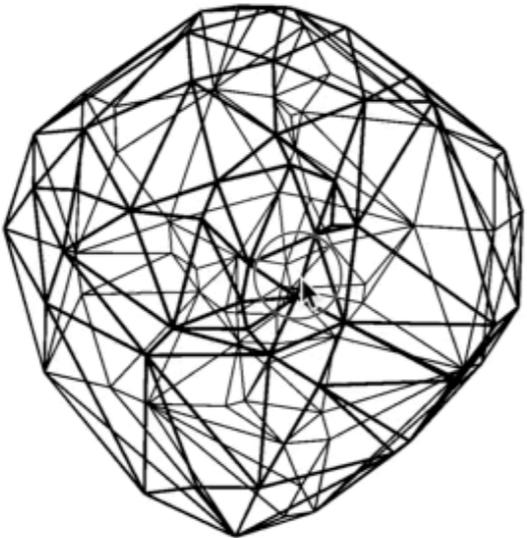
# for point in points:
#     viewer.setStyle(point, makeStyle(fill="#f00"))
|
for seg in segments:
    viewer.setStyle(seg, makeStyle(stroke="#000", strokeWidth=0.5))
viewer.show()
```



jupyter RandomPolyhedraExample (unsaved changes) Logout

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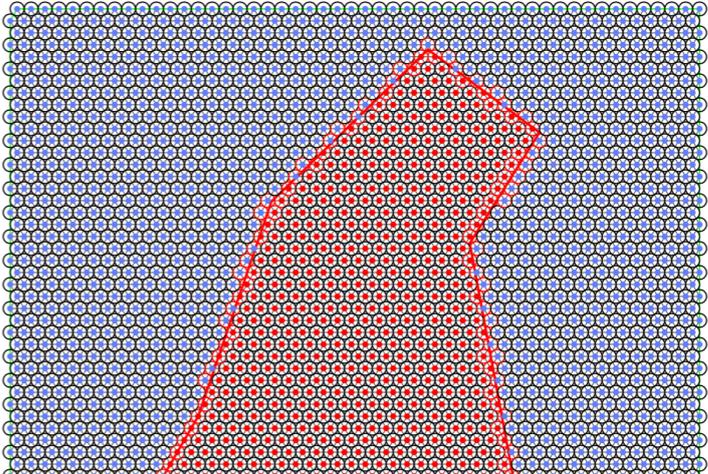
```
viewer.addAll(polyhedron.edges)
viewer.show()
```



jupyter HexGridGeneration (unsaved changes) Logout

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

```
redStroke = makeStyle(stroke="#f00", strokeWidth = 1)
for c in circles:
    if min([seg.distSqTo(c.center)
            for seg in polygon.segments()]) < c.radius * c.radius:
        viewer.setStyle(c, redStroke)
viewer.show()
```



# These Slides

<https://bit.ly/355KrNT>



# More Info

<https://bit.ly/2oUYSUI>