UTSA CS 4593: CS-CURE

Course-based Undergraduate Research Experience in CS

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UTSA CS-CURE

Course-based Undergraduate Research Experience

- Instructor: Dr. Amanda Fernandez
- Resources: Canvas
- Class meetings: Tuesdays & Thursdays 11:30am - 12:45pm BB 3.03.24
- Office hours: Tuesdays & Thursdays 10:15am - 11:30am NPB 3.326
- Grader: TBA

Week 1: **Motivation & Setup**

UTSA CS-CURE

Week 1

- Objectives:
  - Introduce the course, syllabus
  - Begin thinking like a research scientist
  - Identify your field(s) of research interest within CS
- Deliverables:
  - Activity 1 (in class on Thursday)
  - Quiz 0

Research in Computer Science

WHY?

- Develop valuable skills
- Discover your passion & career path
- Boost your resume & open doors
- Deepen understanding
- Personal growth
- Build connections

re·search

/ˈrēˌsərCH,rəˈsərCH/

noun

the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.
"we are fighting meningitis by raising money for medical research"

Similar: investigation | experimentation | testing | exploration | analysis

verb

investigate systematically.
"she has spent the last five years researching her people's history"

Similar: investigate | conduct investigations into | study | inquire into

Research is ***not***…

- "Guess & check"
- Learning an established topic/field/concept
- Completed alone
- Impossible to contribute to

Research

by the numbers

$200 billion

U.S. Government
annual spending on R&D for defense & civilian functions
(Approximation from the NSF FY2023)

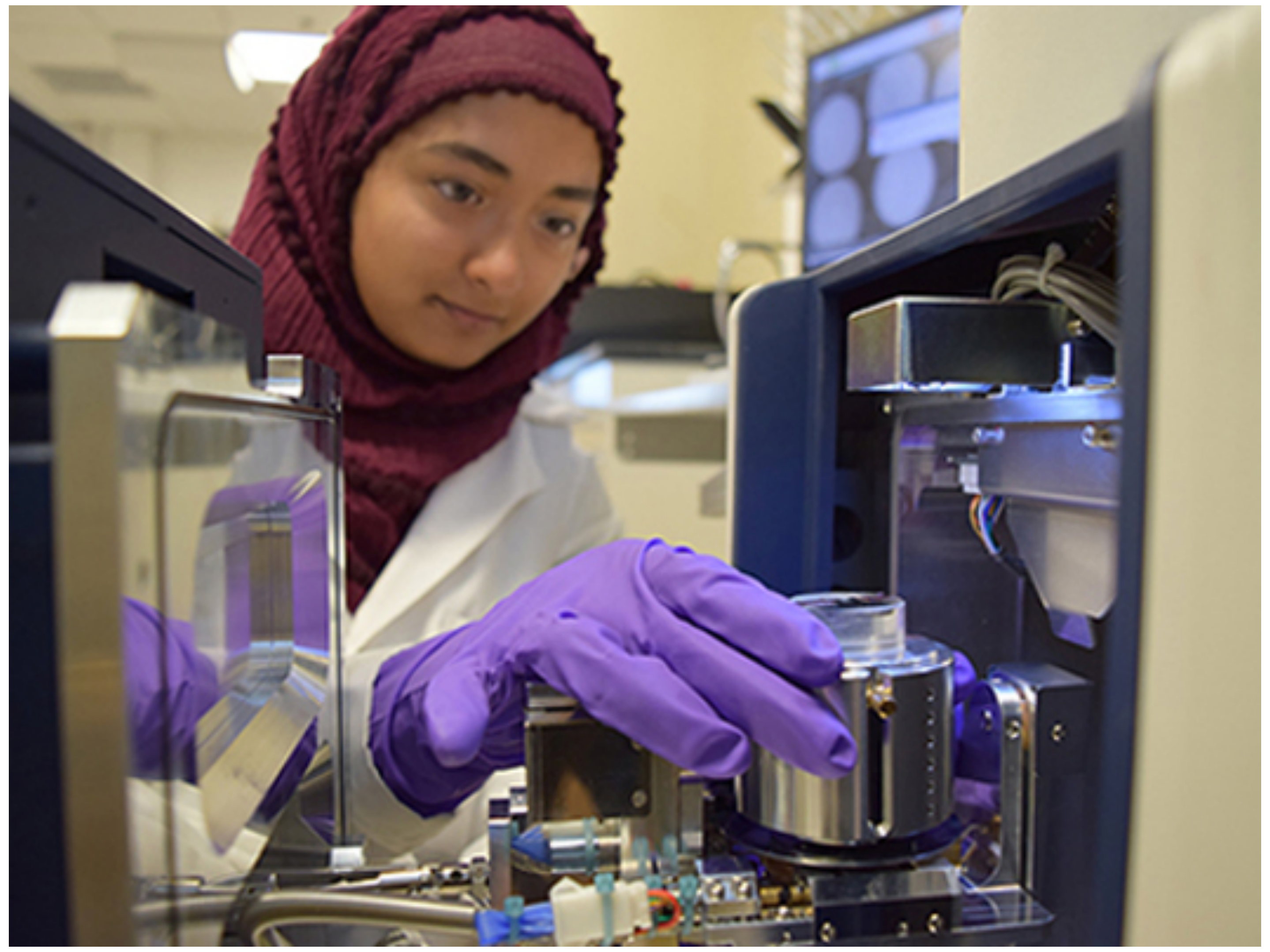
$141 million

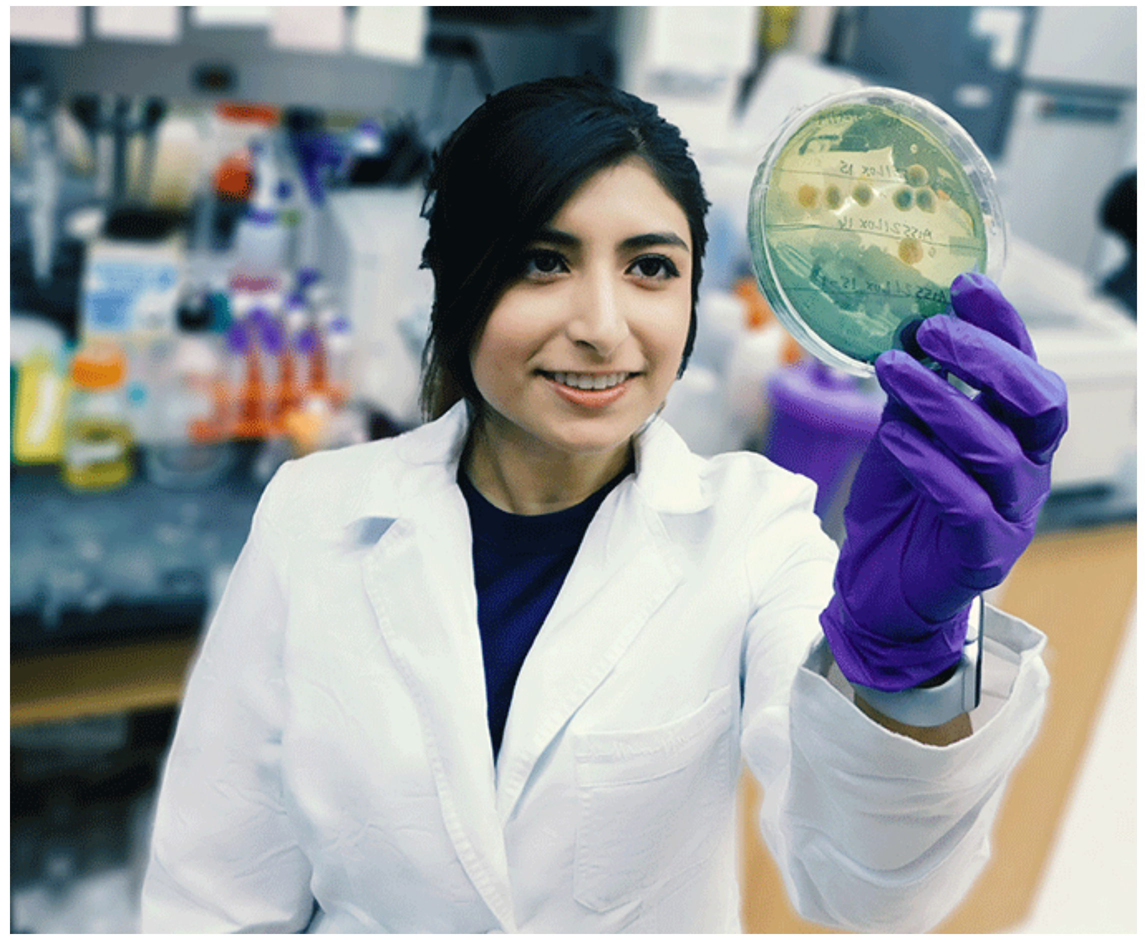
UTSA
annual research expenditures
(UTSA FY 2022 annual report)

"R&D" = research & development
"NSF" = National Science Foundation

"research expenditure" = money spent on research activities.

- "direct" costs = salaries for researchers, benefits, travel, materials
- "indirect" costs = administration costs, tuition/fees for student researchers





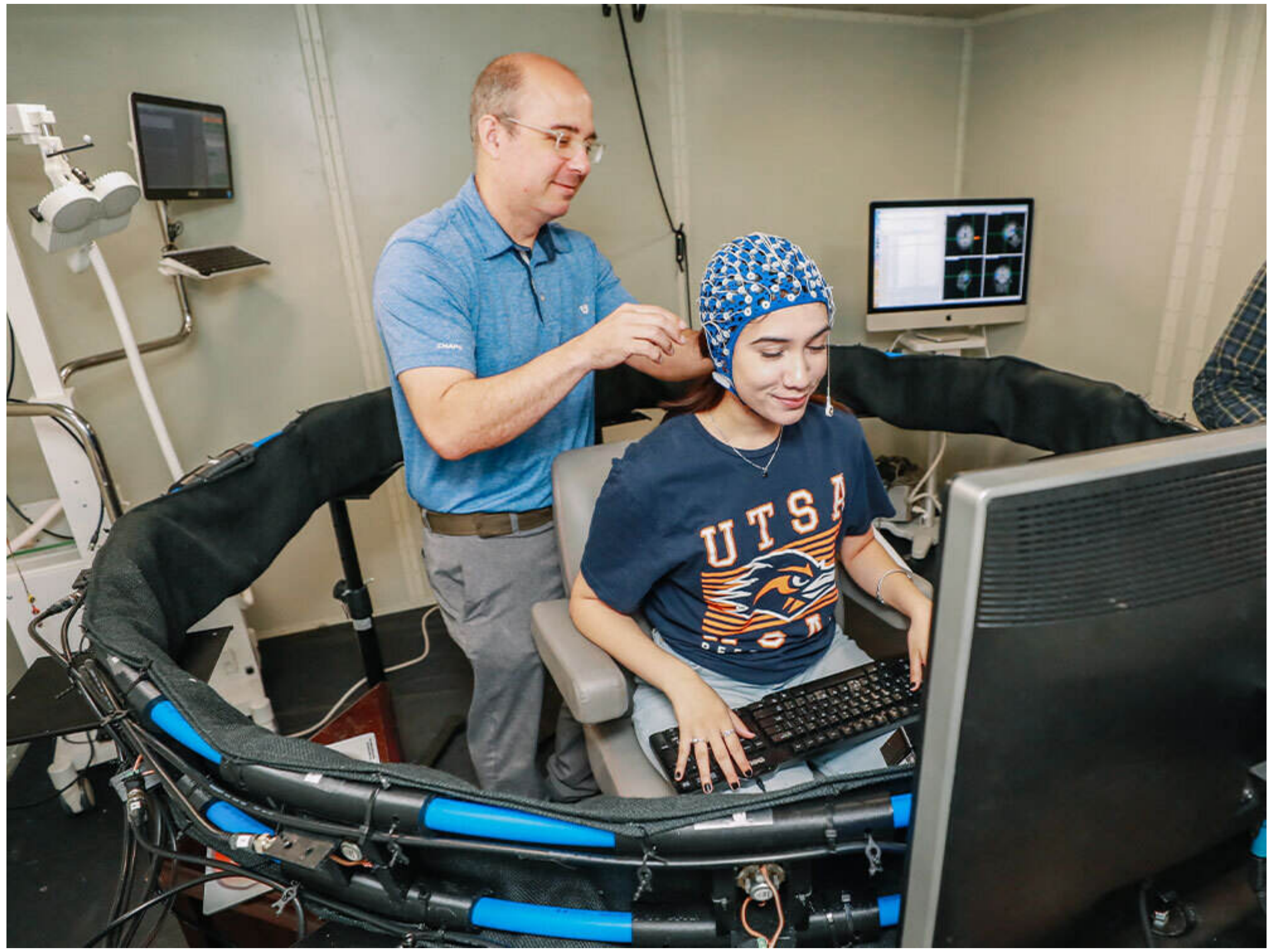


Image source: www.utsa.edu

Research in Computer Science

What does it look like?

- *It varies!*
- Some organizations use a **"technology readiness level"** (TRL) to describe the levels between forming an idea and deploying it commercially.
    - 1-3 = "*basic research*"
    - 4+ = "*applied research*"

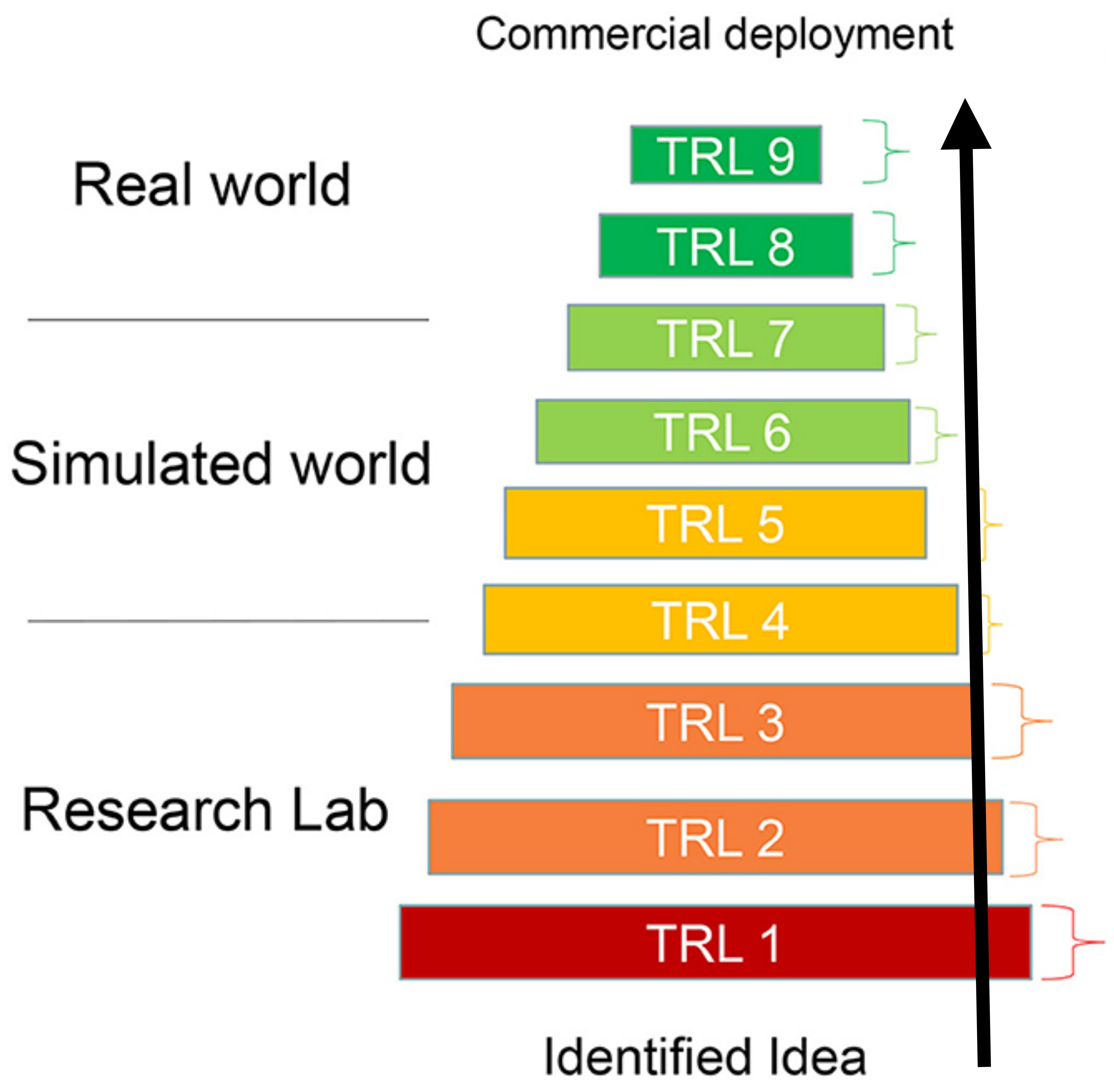


Image source: Arnouts et al, DOI=https://doi.org/10.3389/fvets.2022.1016959

Research in Computer Science

What does it look like?

- Example: **Artificial Intelligence (A.I.)**

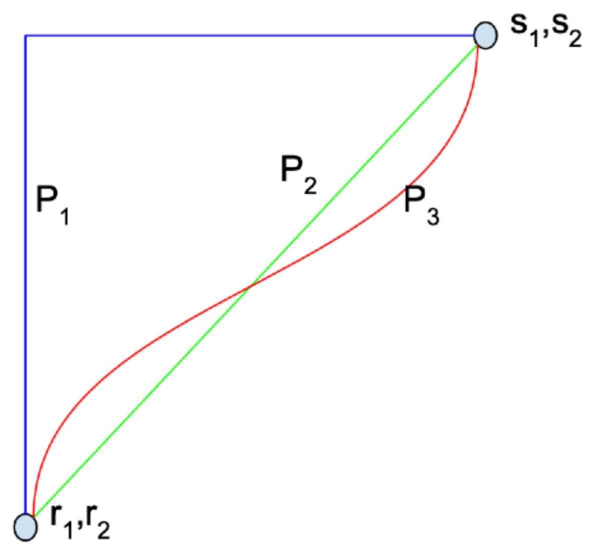
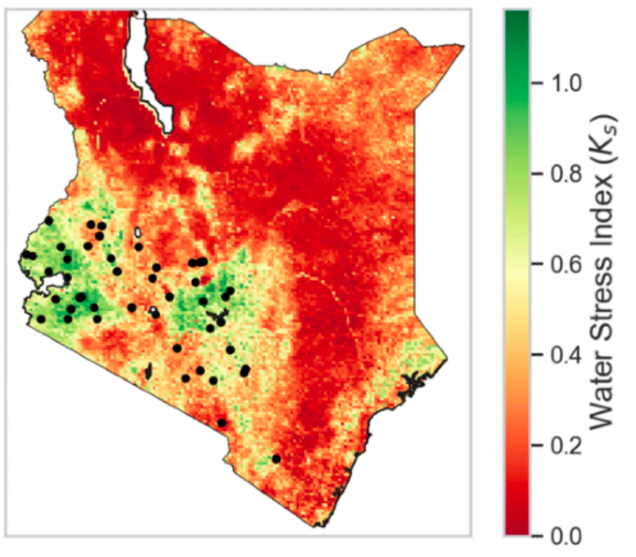


Figure 1. Three paths between an a baseline (r_1, r_2) and an input (s_1, s_2). Each path corresponds to a different attribution method. The path P_2 corresponds to the path used by integrated gradients.

- Basic research = interpretability for deep learning
  - *Axiomatic Attribution for Deep Networks.* [Sundararajan et al, ICML 2017]

- Applied research = AI for social good
  - *Mitigating Low Agricultural Productivity of Smallholder Farms in Africa: Time-Series Forecasting for Environmental Stressors.* [M. Tabar et al, AAAI 2022]

(a) Identified farm locations across Africa.



(b) A heatmap of water stress index (K_s) in Kenya.

Research in Computer Science

What does it look like?

- Example: **Cybersecurity**

- Basic research = formal methods
  - *Formal Methods for Network Performance Analysis.* [*Arashloo et al, USENIX NSDI 2023*]
- Applied research = bug bounty systems
  - *Bug Hunters' Perspectives on the Challenges and Benefits of the Bug Bounty Ecosystem.* [*Akgul et al, USENIX Security 2023*]

Research in Computer Science

What does it look like?

- Example: **Computer Science Education (CSE)**

- Basic research = broadening participation
  - *Socially Responsible Computing in an Introductory Course.* [*Gautam et al, ACM SIGCSE 2024*]
- Applied research = developing teaching strategies
  - *Pairing Ungrading with Project-Based Learning in CS1 for Inherently Flexible Course Design* [*Smith, ACM SIGCSE 2024*]

Research in Computer Science

How can I get involved?

- **Become a researcher**
    - Undergraduate Research Assistant (URA)
    - Graduate Research Assistant (GRA)
    - Postdoctoral Researcher (postdoc)
- **Volunteer**
    - Clinical trials
    - Citizen science
    - Volunteer for research studies
- **Support**
    - Advocate & raise awareness
    - Donate to fund research or leverage your skills

citizenscience.gov

Research in Computer Science

So many questions!

- *Do I need an advanced degree?*
- *Should I do “basic” research or “applied”?*
- *How should I pick a program/advisor/lab?*
- *What jobs are there in CS research?*
- *What does a day in the life of a researcher look like?*
- *How do I find a topic that is interesting to me?*
- *Is there active research/funding in my field of interest?*
- *How do I find people with similar interests?*
- *How do I get caught up with my field?*
- *What’s an IRB, and do I need it?*
- *…..*

Our goal is to answer <u>your</u> questions through this course.

What do **YOU** want to know?

What is a CURE?

What is a CURE?

Course-based Undergraduate Research Experience

= courses offered by specific (often science or engineering) departments with the following elements:

1. There is an element of discovery, so that students are working with novel data.
2. Iteration is built into a lab or engagement activity.
3. Students engage in a high level of collaboration.
4. Students learn scientific practices.
5. The topic of research is broadly relevant so that it could potentially be published and/or of interest to a group outside the class.

(Auchincloss et al. 2014)

What is a CURE?

Course-based Undergraduate Research Experience

In general, research engagement must have the following attributes:

- Attribute 1: Research design should be based on the established philosophical stances that are scientifically valid relative to the field of study. Where borrowing or learning from another field of study, a clear justification must be provided.
- Attribute 2: The design should employ research techniques and methodological approaches that have proven dependable and reliable and that are directly relevant to the nature of the research problem.
- Attribute 3: Research design should be structured to avoid unscientific hypothesis formulation, subjectivism and bias.
- Attribute 4: The analytical discussion should avoid speculation and present well-reasoned analytical arguments.
- Attribute 5: The research should be monitored and take place in a controlled environment (quantitative research) or within a relatively limited scope (quantitative and qualitative research).
- Attribute 6: The research should adopt rigorous and structured procedures.
- Attribute 7: Research should be logical and systematic.
- Attribute 8: The final research output and the research manuscript should have a valid, verifiable conclusion.
- Attribute 9: In some cases, the research manuscript should present an empirical conclusion.

Jannach et al. (2012)

What is CS-CURE?

Course-based Undergraduate Research Experience in CS @ UTSA

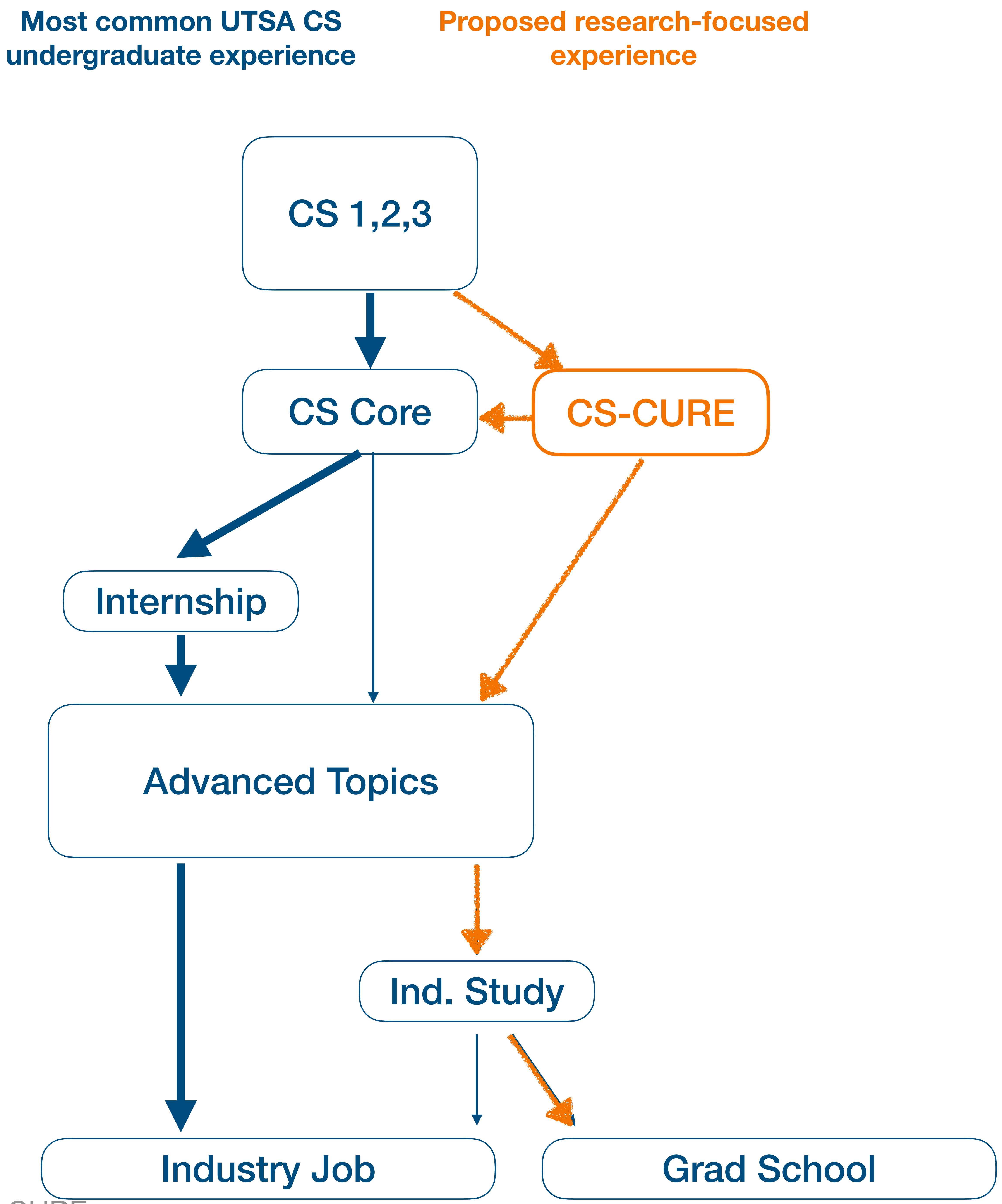
- It is **not** an independent study.
- It is a structured course on research methods, with a focus on research for new/beginning computer scientists. Consists of:
    - **Lectures** - new materials & tools needed to understand research in CS
    - **Activities** - designed to reinforce the new concepts & enable hands-on experience
    - **SIG meetings** - engaging with peers who have similar interests
    - **Guest lectures** - focused research talks on a variety of CS topics

Motivation for CS-CURE at UTSA

- 1900+ undergraduate CS majors

  Plus 119 masters students, 71 PhD students. Faculty: 26 T/TT and 18 FTT. [Fall 23]

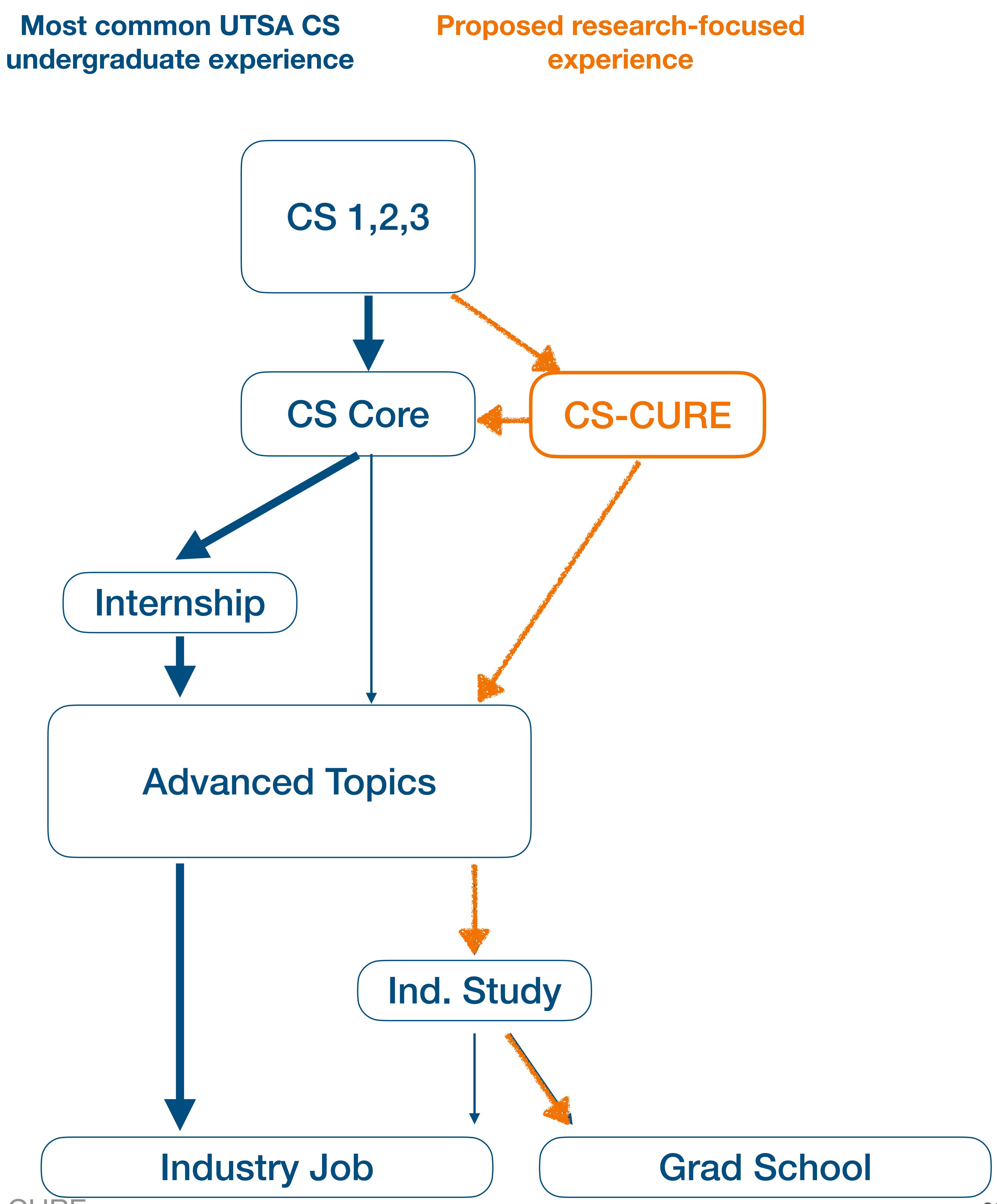
- **CS-CURE** is designed to provide a scalable solution to undergraduate research engagement in our department.
  - Study <u>your</u> topic of interest (in CS)
  - Engage with peers with similar interests
  - Build skills necessary to impact your field



CS-CURE at UTSA

Important notes:

- **CS1 is the only prerequisite**
    - (There will be a range of student expertise in the class)
- **The course is generalized to all CS**
    - (The course will focus on research “how to”, and you will focus on applying it to your field)



What is CS-CURE?

TL:DR

- *Tuesdays* = general content on research in computer science
- *Thursdays* = in-class activities applying the concepts to <u>your</u> research topic

Syllabus

Special Interest Groups (SIGs)

Special Interest Groups (SIGs)

Peers in the field

Critical to *each step* in the research process..

- Identifying relevant topics
- Evaluation metrics for experiments
- Data analysis techniques
- Reporting conclusions

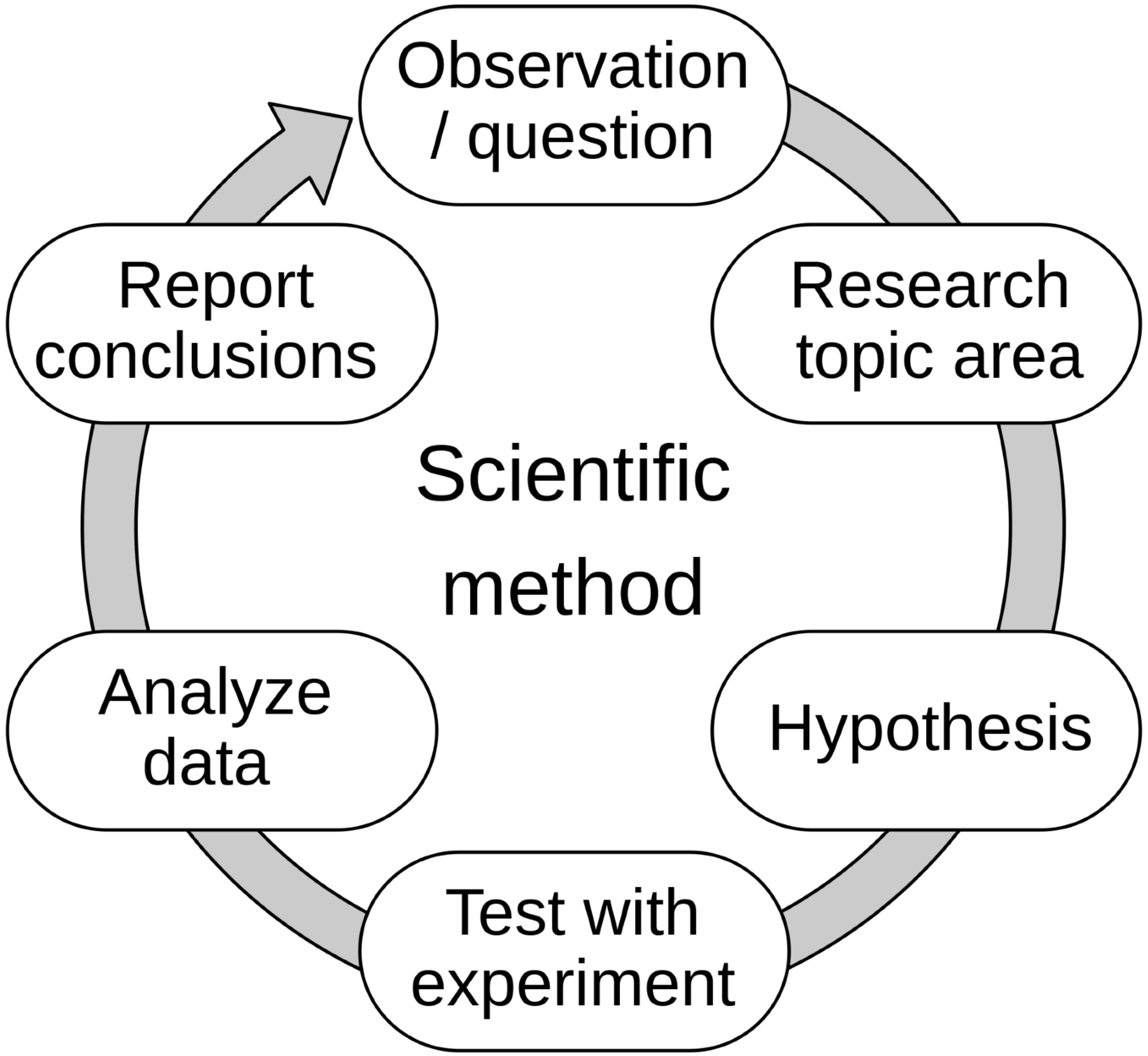


Image source: Wikipedia

Special Interest Groups (SIGs)

Communities or subgroups within a larger organization or association that share a common, specific interest, focus, or goal.

- Formed to bring together like-minded individuals who have a passion for a particular area within a broader field or discipline.
- Provide a platform for members to collaborate, exchange ideas, and work on projects related to their shared interest.
- Can be found in various domains, including academia, professional organizations, and hobbyist groups.

Special Interest Groups (SIGs)

Key characteristics

- **Focused Interest:** SIGs have a well-defined and specific interest, often within a larger field. This focus allows members to engage deeply in discussions and activities related to their shared interest.
- **Membership:** SIGs attract individuals who share a common passion or professional interest. Members may come from diverse backgrounds but are united by their focus on a particular niche.
- **Activities:** SIGs often engage in various activities, such as organizing events, conferences, webinars, workshops, or publishing newsletters and journals related to their field of interest.
- **Collaboration:** Members collaborate on projects, research, or initiatives related to their interest. They may also share resources, knowledge, and experiences.
- **Autonomy:** SIGs often have a degree of autonomy within the larger organization or association. They may have their own leadership, governance, and decision-making processes.
- **Networking:** SIGs offer members opportunities to network with others who share similar interests, which can lead to collaborations and career opportunities.

TL;DR:
There are lots!

Wrap-Up

Tuesday

- Motivations for research
- CS-CURE course setup

- To Do:
    - *What topic area within CS seems most interesting to you?*
    - Complete **Quiz 0** on Canvas

Mostly survey questions!

See you Thursday!

Activity 1: **Research Basics**

Activity 1: Research Basics

Thursday

1. Introduction

2. Finding your field of interest and previewing topics

3. In-class activity (*turn in by end of class)*

4. Wrap-up discussion

Activity 1: Research Basics

Introduction

- Research can be overwhelming if too broad…let's take small steps:

  1. *Narrow down your field within CS* **This week**
  2. *Review interesting topics in the field* **Next week**
  3. *Investigate open questions in the field* **Later in the semester**
  4. *Come up with a hypothesis or question of your own*

This is when you'll start to see smaller groups of the same researchers!

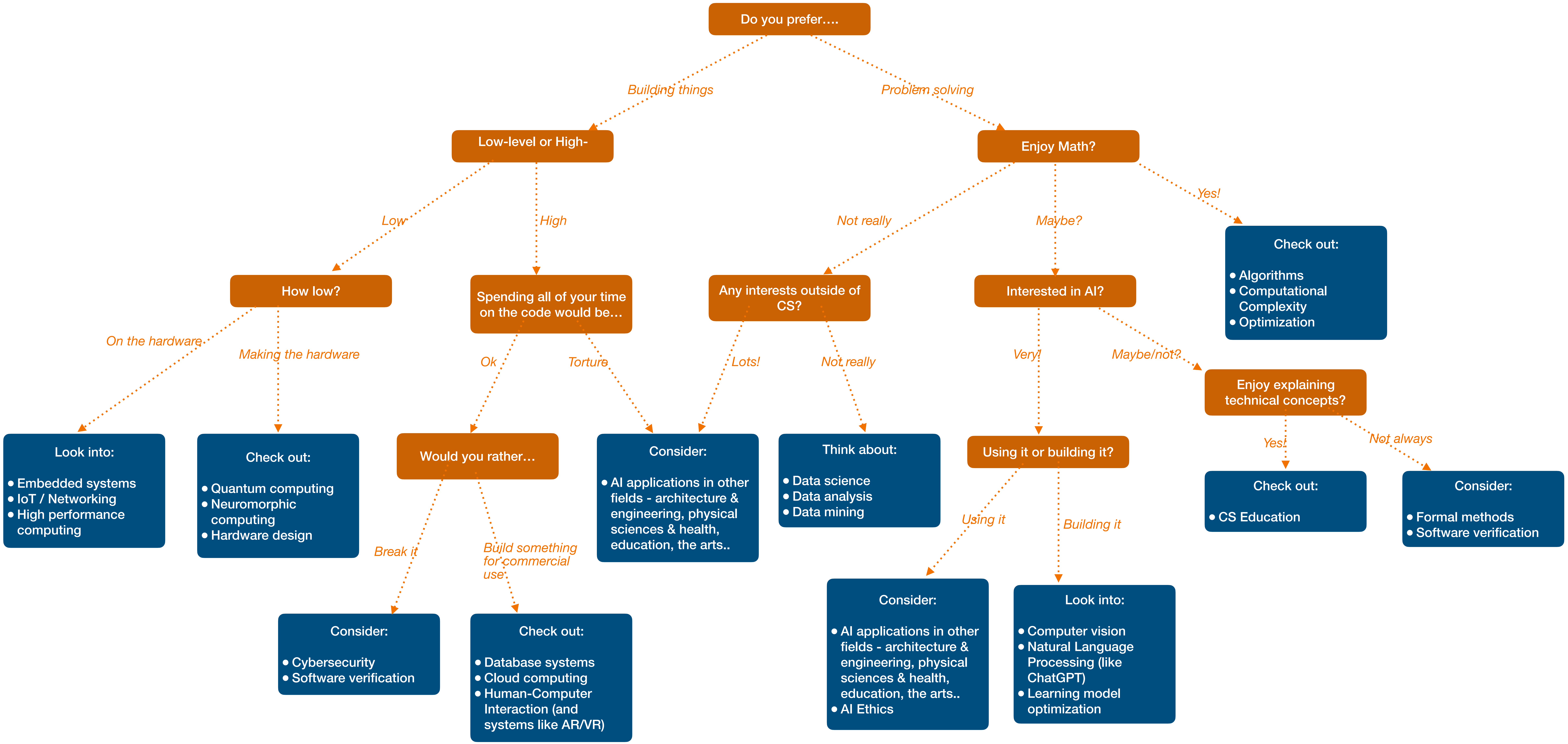
Activity 1: Research Basics

Finding Your Research Interest

- Handout 1: **CS interests question flowchart**
    - *Activity*: reflect on your likes & dislikes within CS
    - *Goal*: identify a field (or combination of fields) you enjoy the most

- Handout 2: **Research topic “bingo”**
    - *Activity*: preview some research topics across a range of CS fields
    - *Goal*: look for trends among the topics you might be interested in (and among those you are not)

Activity 1: Finding Your CS Research Field



<u>Instructions</u>:
Beginning at the top, answer the questions (honestly!) to discover which Computer Science research fields might be of interest. **<u>Circle</u>** the blue boxes that correspond with a good match to your answers, and **<u>cross out</u>** any that are not of interest. Leave the rest unmarked.

Activity 1: Finding Your CS Research Field

Building a Secure and Scalable Decentralized Cloud Storage System	Designing secure communication protocols that resist vulnerabilities like eavesdropping, data manipulation, and denial-of-service attacks.	Towards Secure and Reliable Quantum Computing Hardware	Constructing consistent digital line segments
Investigating resource sharing and trading mechanisms between edge nodes to optimize utilization	Designing feedback mechanisms that provide meaningful and actionable insights to support student learning and program improvement.	Efficiently segmenting images with texture	The Computational Complexity of Quantum Annealing
Developing efficient algorithms and hardware architecture for performing machine learning tasks directly on embedded devices.	Establishing fairness metrics for AI models	Developing efficient data partitioning and aggregation techniques for distributed ML architectures	Leveraging explainable AI for anomaly detection large datasets
Leveraging Explainable AI for Real-Time Medical Diagnosis	Building privacy-preserving data mining solutions for bioinformatics	Developing new techniques for visualizing and interacting with real-time data streams in AR/VR environments	Designing distributed and parallel data mining algorithms for processing large datasets on cloud platforms

Instructions:
Review each research topic. **Circle** any topics you might want to read more about *right now*, and **cross out** any that are not of interest. Leave the rest unmarked.

Systems Theory

Building a Secure and Scalable Decentralized Cloud Storage System	Designing secure communication protocols that resist vulnerabilities like eavesdropping, data manipulation, and denial-of-service attacks.	Towards Secure and Reliable Quantum Computing Hardware	Constructing consistent digital line segments
Investigating resource sharing and trading mechanisms between edge nodes to optimize utilization	Designing feedback mechanisms that provide meaningful and actionable insights to support student learning and program improvement.	Efficiently segmenting images with texture	The Computational Complexity of Quantum Annealing
Developing efficient algorithms and hardware architecture for performing machine learning tasks directly on embedded devices.	Establishing fairness metrics for AI models	Developing efficient data partitioning and aggregation techniques for distributed ML architectures	Leveraging explainable AI for anomaly detection large datasets
Leveraging Explainable AI for Real-Time Medical Diagnosis	Building privacy-preserving data mining solutions for bioinformatics	Developing new techniques for visualizing and interacting with real-time data streams in AR/VR environments	Designing distributed and parallel data mining algorithms for processing large datasets on cloud platforms

Applications Data

Instructions:
Review each research topic. **Circle** any topics you might want to read more about *right now*, and **cross out** any that are not of interest. Leave the rest unmarked.

Activity 1: Research Basics

Special Interest Groups (SIGs)

- Part 1: **Forming [initial] SIGs**
  - *Activity*: physically relocate within the class to be near folks in your field
  - *Goal*: test drive a SIG for the day

- Part 2: **Discussions & Activity 1 Worksheet**
  - *Activity*: complete the Activity 1 worksheet (***to be turned in at the end of class***)
  - *Goal*: initiate discussions among peers with similar interests, consider whether

Activity 1: Research Basics

Special Interest Groups (SIGs) - Activity part 1

- Let's try to form groups according to field of interest:
  - AI
  - Computing Foundations
  - CS Education
  - Cybersecurity
  - HCI
  - Software Engineering
  - Systems
  - *Other*
  - *"I have no idea"*

I will help balance the groups if/ where needed.

This is not a commitment to the topic for the semester (yet!)

Activity 1: Research Basics

Exploring Potential Topics - Activity part 2

1. Reflect on the 2 handouts and your experiences with them
2. Discuss your experience in the field related to your SIG
3. Complete the activity handout (*requires some discussion with your new research community!)*

Wrap-Up

Thursday

- Exploring research topics of interest to you
- Investigating recent research
- Discussion within a research community

- <u>To Do</u>:
    - Complete **Quiz 0** on Canvas

See you next week!

Mostly survey questions!