

The Scientific Method

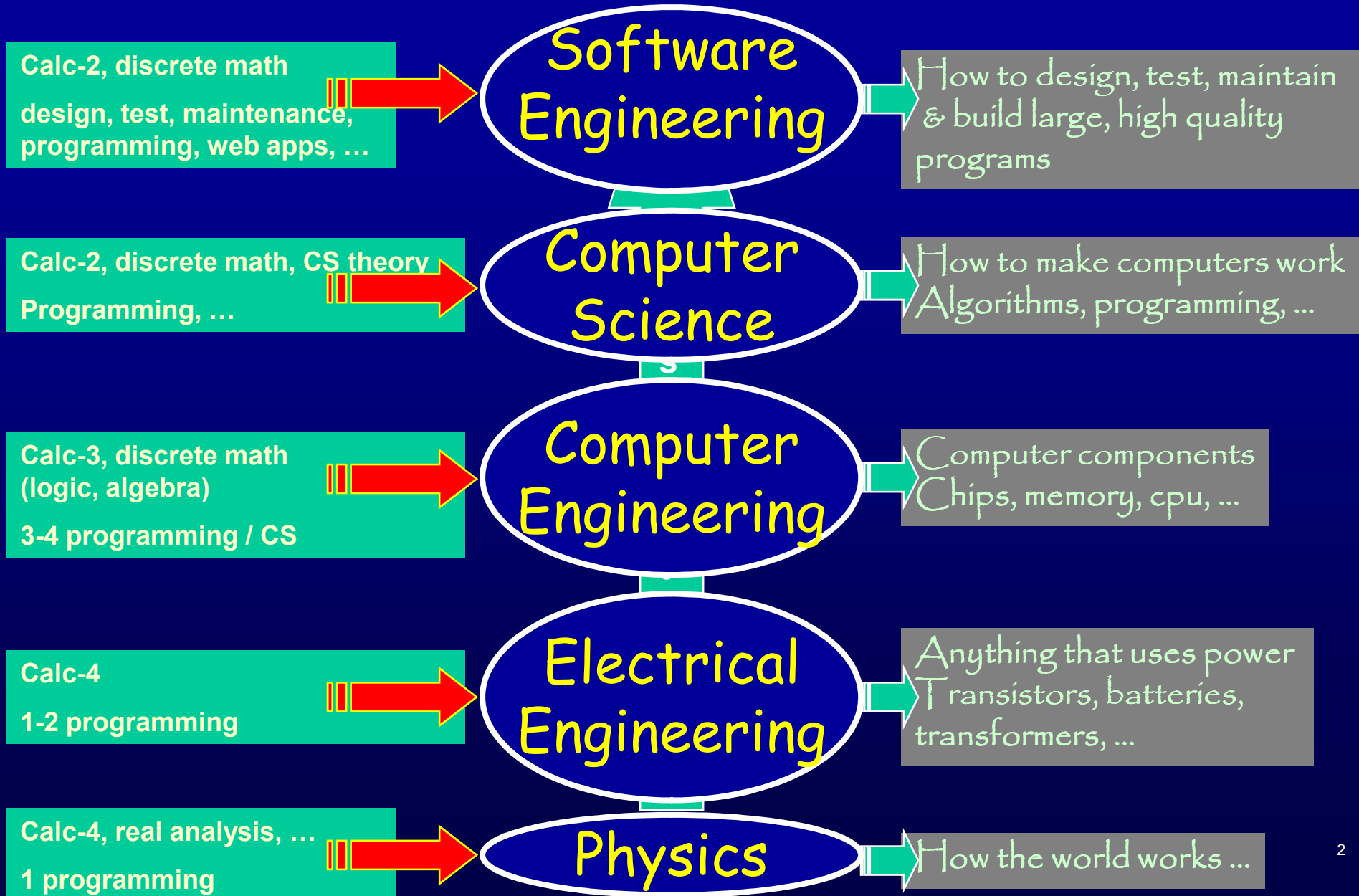
**(adapted from a PhD Seminar
and
a High School Talk)**

James Baldo Jr.

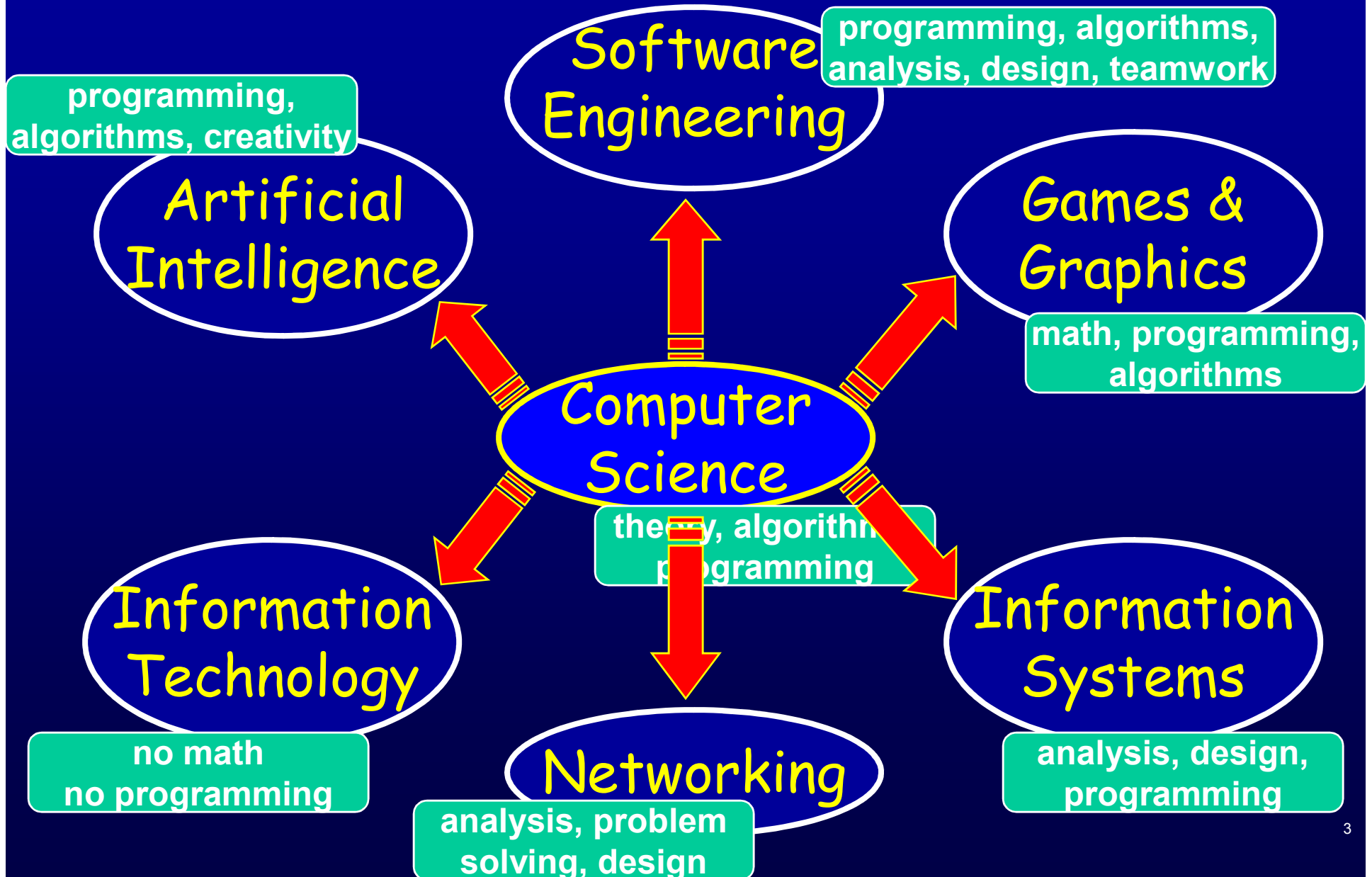
SWE 432

Design and Implementation of Software for the Web

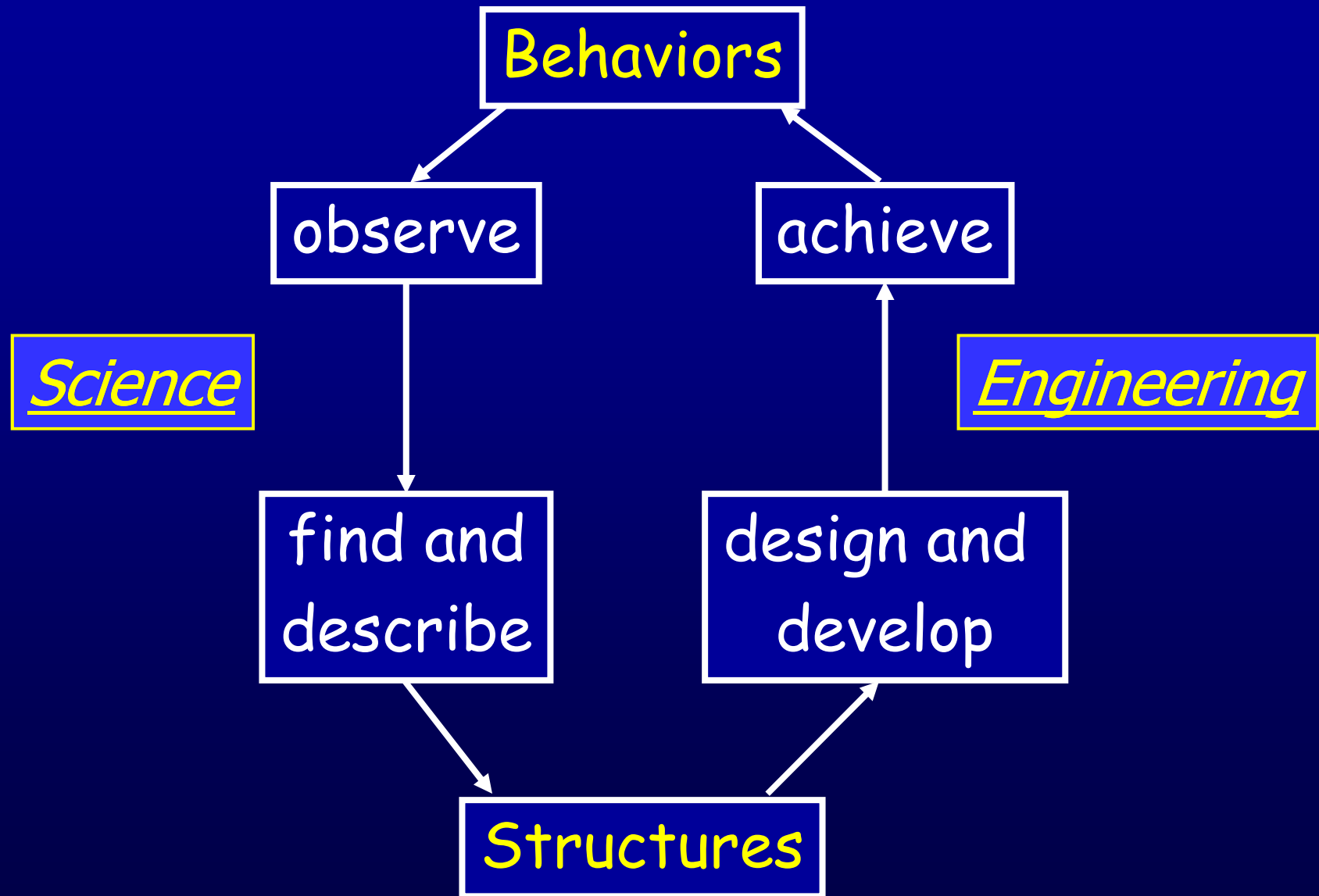
Comparing Computing Fields



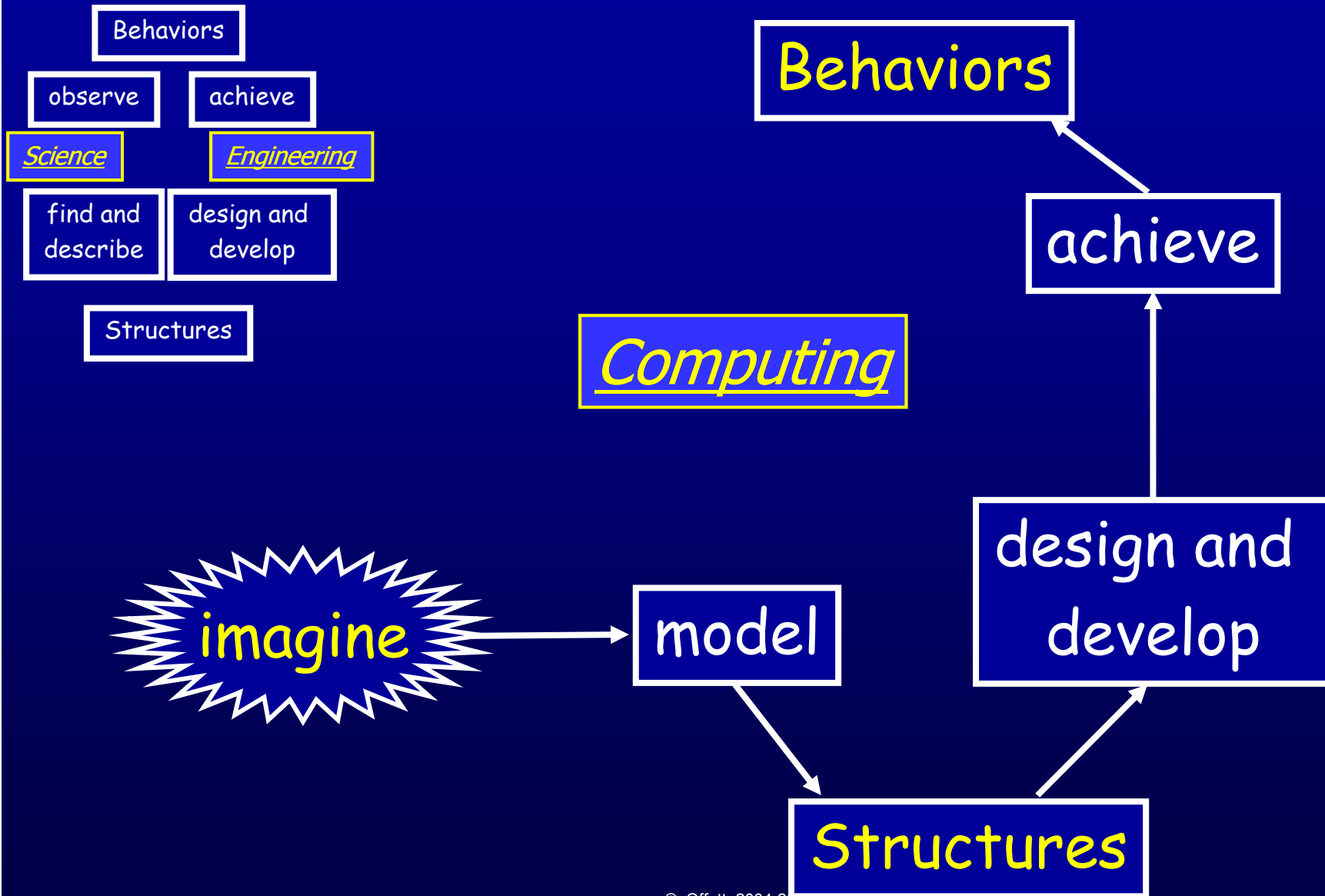
Computing Areas (2020)



Goals of Science and Engineering



Computing Doesn't Quite Fit



Measuring and Science

When you can measure what you are speaking about, and express it in numbers, you know something about it.

– Lord Kelvin, 1889

<http://zapatopi.net/kelvin/quotes.html>

What is a Scientific Test

- The Budweiser Test

- In a bar, people who liked another brand best were given a “live” challenge – which beer is better?

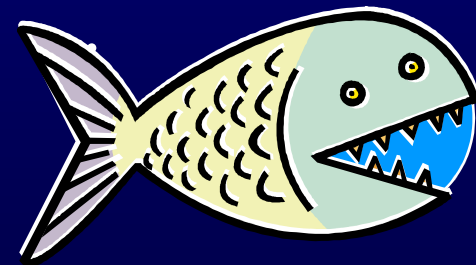
- Results?

- 50% chose Budweiser over their favorite beer!!!

- Conclusion:

- Budweiser is better !!!

- Hmm ... something's fishy



Scientific Test

- **Test:** Live TV, lots of noise and confusion, subjects had already been drinking ...
- Subjects wouldn't be able to tell any difference, so we should expect each beer to be chosen ...
- **Half the time!**
- There are **three** kinds of lies ...

Lies, Damn Lies, and Statistics



Eating and Talking

- **Japanese** eat very little fat and suffer fewer heart attacks than **British** or **Americans**
- On the other hand, **French** eat a lot of fat and also suffer fewer heart attacks than **British** or **Americans**

Conclusion: Eat what you like. It's speaking English that kills you.

Be Careful Who You Fool

The first principle is that you must not fool yourself – and you are the easiest person to fool.

— Richard Feynman (*Nobel Physics, 1965*)

Noone in this world is easier to deceive and mislead than someone who thinks that he is smarter than you are.

— David Eddings (*Author*)

We all think we're smarter than we are.

— Jeff Offutt (*prof*)

Six Ways to Acquire Knowledge

1. Tenacity
2. Intuition
3. Authority
4. Rationalism
5. Empiricism
6. Science



1. Tenacity

Knowledge based on superstition or habit

- Examples:
 - “Good research can only be done when you’re younger than 30”
 - “Gay people are bad”
 - “OO design has too many subroutine calls and is too inefficient”
- Exposure: The more we see something, the more we believe
- Tenacity has
 - No guarantee of **accuracy**
 - No mechanism for **error correction**
- Knowledge from tenacity is **prejudism**



2. Intuition

Guessing: An approach that is not based on reasoning or inference

- Examples:
 - I think he is a nice person
 - It's probably going to rain today
- We do not really understand why we believe it
- No way to separate accurate from inaccurate knowledge
- Can be used to form hypotheses
- Can be very misleading



3. Authority

Accepted because it comes from a person with authority

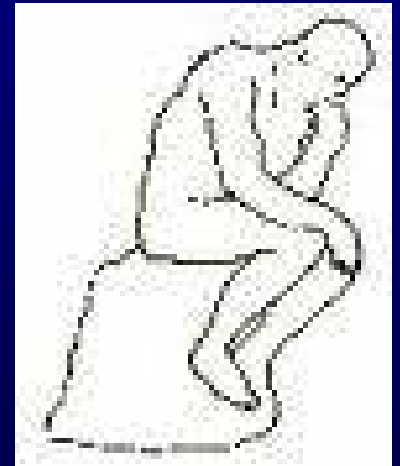
- Examples:
 - Rules our parents taught us
 - Religion
 - Totalitarian government
- No evidence given
- No way to **validate or question** the knowledge
- Not the same as asking an **expert** – we can accept, reject, or challenge an expert
 - In grade school, teachers are treated as authorities
 - In college, teachers are experts



4. Rationalism (Reasoning)

Acquiring knowledge through reasoning

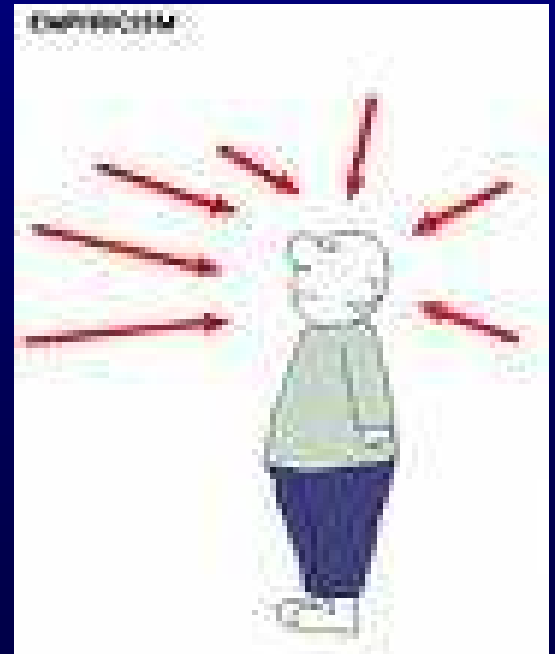
- Logical deduction
- Assume knowledge is correct if the correct reasoning process is used
- Middle ages relied almost exclusively on rationalism
- Important for theory and pure math
 - A mathematical proof is rationalism at its best
 - Theoretical physics ... experimental physics
- Easy to reach incorrect conclusions
 - False premises
 - Mistakes in the reasoning or steps skipped
- Use rationalism to arrive at a hypothesis, then test with the scientific method



5. Empiricism

Acquiring knowledge through experience

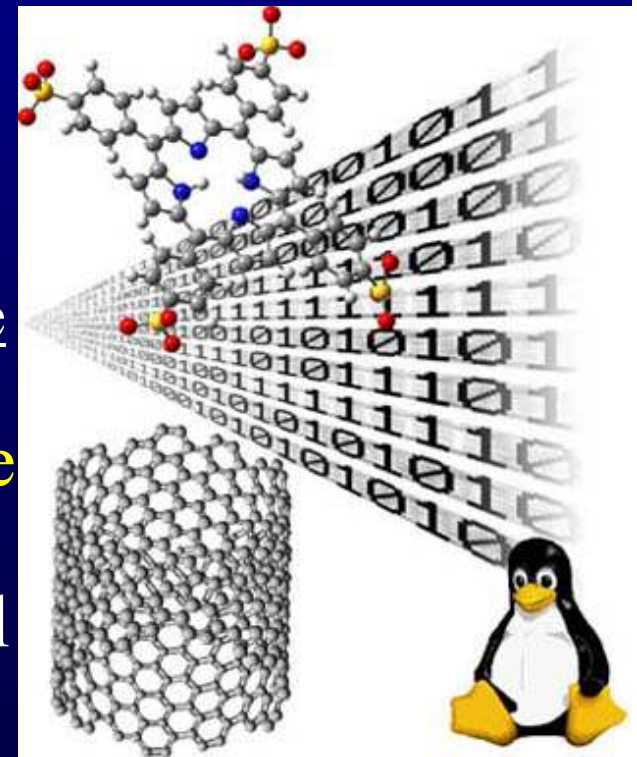
- “I have experienced it, therefore it is true”
- Experience is subjective and hard to control
- “I drove home 3 times after drinking without having an accident, so drunk driving
 - Were you lucky ?
 - How severe are the consequences of an accident ?
- Much of **computer “science”** is just empiricism



6. Science

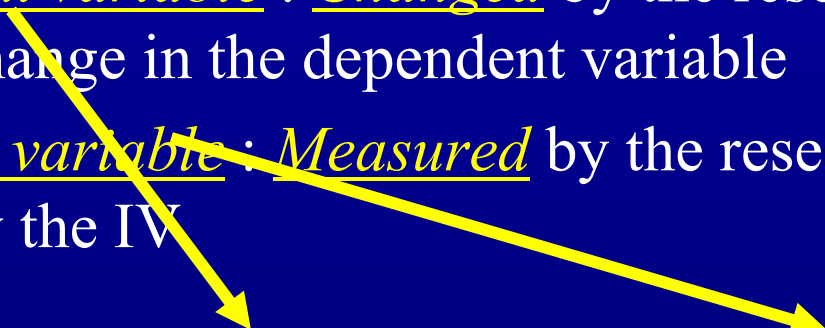
Testing ideas empirically according to a specific testing procedure that is open to public inspection

- Based on **reality**
 - Scientists have to look at the fire, not the shadows
- Separate **personal beliefs**, perceptions, biases, attitudes, emotions
 - We all have biases; science helps us ignore them
- Based on **objectively observed evidence**
- Hypotheses, independent variables, dependent variables, controls, statistical validation



Experimental Variables

- Independent variable : Changed by the researcher to determine if it causes a change in the dependent variable
- Dependent variable : Measured by the researcher to determine if it is affected by the IV



Does intelligence make people better drivers ?

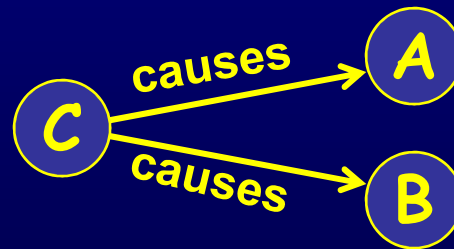
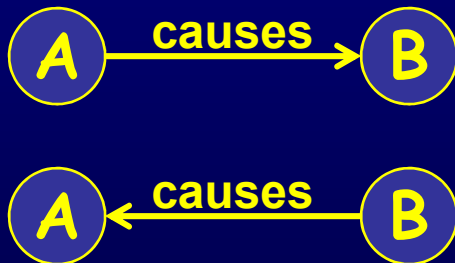
- Confounding variables : Other explanations for the results
 - Driving skills of parents, amount of time driving, emotional problems
- Measured variable : If the dependent variable cannot be directly measured, we measure a related variable to approximate
 - Accidents, tickets, attempts to pass the driving test, drivers Ed grade

How Valid are the Results ?

- External validity : Whether the results in the study will be the same in other situations
 - Were the subjects “representative” ?
 - I only looked at CS majors... special kids
- Internal validity : Whether the change in the Dependent Variable was controlled by the Independent Variables
 - Did we miss a confounding variable ?

Correlation and Causality

- Correlated: Two things always happen at the same time
 - Brake lights **and** car slowing down
- Causality: Understanding what causes something to happen
 - Brake light **causes** the car to slow down ?
- If **A** and **B** are correlated:



Pressing brake activates brake light AND slows car down ...



Confusing Correlation and Causality

- In “*the old days*”, we believed that being cold caused us to get colds



- Colds are caused by viruses, not temperature
- Viruses breed in warm, damp, low-oxygen, carbon-dioxide rich environments
- In cold weather, we close our windows and turn up the heat ... creating ...
- Virginia gets a secondary cold season in *July-August* ... when the weather turns *hot* and *humid* ...

Cognitive Dissonance

- We feel uncomfortable when new data contradicts our beliefs
- Revising our mental model to accommodate new data is hard
 - We resist new ideas
 - I miss **Pluto** !!!



Scientists must be open-minded

**Allow facts to replace knowledge gained by
tenacity, intuition and authority**

Be Problem Solvers

- As Computer Science / Software Engineering majors, you have proven yourselves to be good **problem solvers**
- Much of life is about **solving problems**
- Education is not about **skills**, it is about **knowledge**
- Utilize your education knowledge to help you:
 - Think **rationally**
 - **Question** authority
 - Solve all of **life's problems**



UI Evaluations

- The purpose of the UI evaluations is to train you to evaluate :
 - Objectively
 - Rationally
 - Quantitatively
 - Empirically

In short, to be scientists