THE SCIENTIFIC METHOD 2.0

ENHANCING CRITICAL THINKING FOR TODAY'S CHALLENGES

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A BRIEF HISTORY OF LEARNING

- 30 years ago, we did every other odd problem in the back of our text for Every. Single. Course. we took.
  - Critical thinking was a must. We had to read the text to figure out the reasoning.
- 15 years ago, we could google on our computer anything and find much of what we wanted (solved problems anyone?)
- Today, we have the world of information at our fingertips, and if we cannot find what we are looking for, AI will help.
  - Easy to dismiss critical thinking with answers so easily available BUT we always must assess the validity of our information.

WHAT IS CRITICAL THINKING

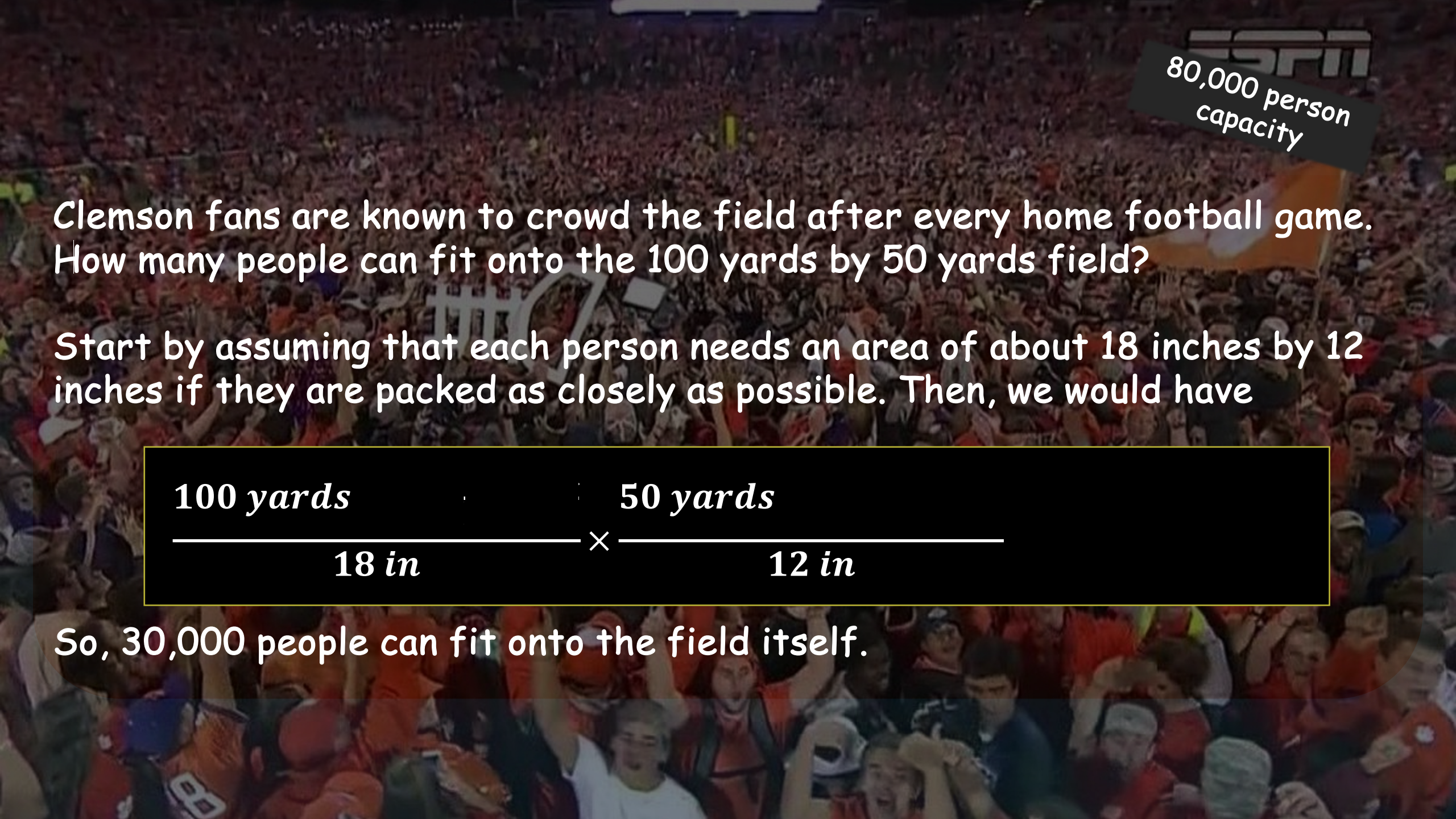
- Ability to analyze, reason, and draw valid inferences based on evidence.
  - think critically about the underlying principles
  - solve complex problems
  - make logical decisions
- Students must understand, apply their knowledge and arrive at logical conclusions.
- Physics provides a foundation for developing these skills, allowing students to investigate the natural world, conduct experiments, and analyze their observations

DON’T THROW THE BABY OUT WITH THE BATHWATER

- The internet and AI have fundamentally changed how students interact with information
  - Can look up constants and formulas
  - Can find out large amounts of information on any topic, *quickly*.
  - Have AI distill articles and information into easily accessible chunks.
- Today's students will not access material in the same manner that we did.
- Due to the instancy of information, critical thinking is even more important to today's students.

FOCUS ON CRITICAL THINKING BY BRINGING THE MESS OF LIFE INTO THE CLASSROOM

- Life is full of competing priorities.
- Students are focused on completing their to-do list.
- Easy to fail to see the connections between our real life and the topic we are studying.
- Without a reason to “master” the material many students just focus on passing the class or completing their tasks.
- Bringing the mess of life into the classroom engages students with the opportunities to practice course concepts and reinforces critical assessment of information.



Clemson fans are known to crowd the field after every home football game. How many people can fit onto the 100 yards by 50 yards field?

Start by assuming that each person needs an area of about 18 inches by 12 inches if they are packed as closely as possible. Then, we would have

$$\frac{100\ yards}{18\ in} \times \frac{50\ yards}{12\ in}$$

So, 30,000 people can fit onto the field itself.

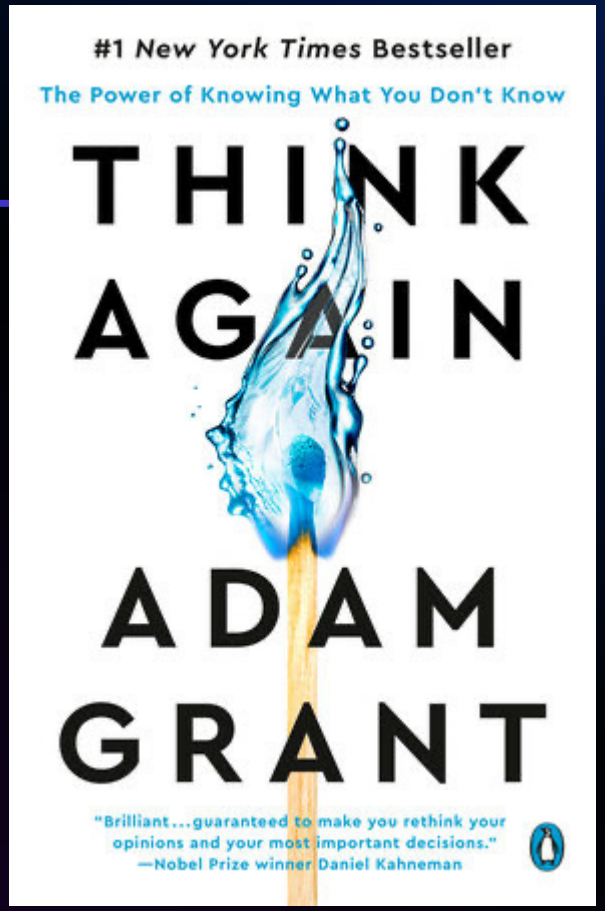
KEY 1: QUESTIONING ASSUMPTIONS

We must challenge assumptions and remain open to changing our minds.

Cognitive entrenchment is the tendency of our beliefs and attitudes to become rigid and resistant to change.

Common case and point:

Heavier Objects Fall Faster Than Lighter Objects.



KEY 1: QUESTIONING ASSUMPTIONS

We learn through the confrontation of misconceptions

Babies learn to walk by understanding their center of mass, forces, and gravity intuitively.

We all have “rules” we have established that are simply not correct.

Unlearning these rules is critical to understanding.

We confront misconceptions by having to explain them to others (or ourselves).

KEY 1: QUESTIONING ASSUMPTIONS

Let's confront our assumption by explaining something easy …left and right …to an alien civilization.

We use right- and left-handed coordinate systems, clockwise and counterclockwise. These terms are often used to explain orientations in science.

In a purely verbal manner explain right and left to an alien.

https://www.scientificamerican.com/blog/degrees-of-freedom/handedness-galactic-challenge/

KEY 1: QUESTIONING ASSUMPTIONS AS A STUDY TOOL

Talk to your pencil strategy.

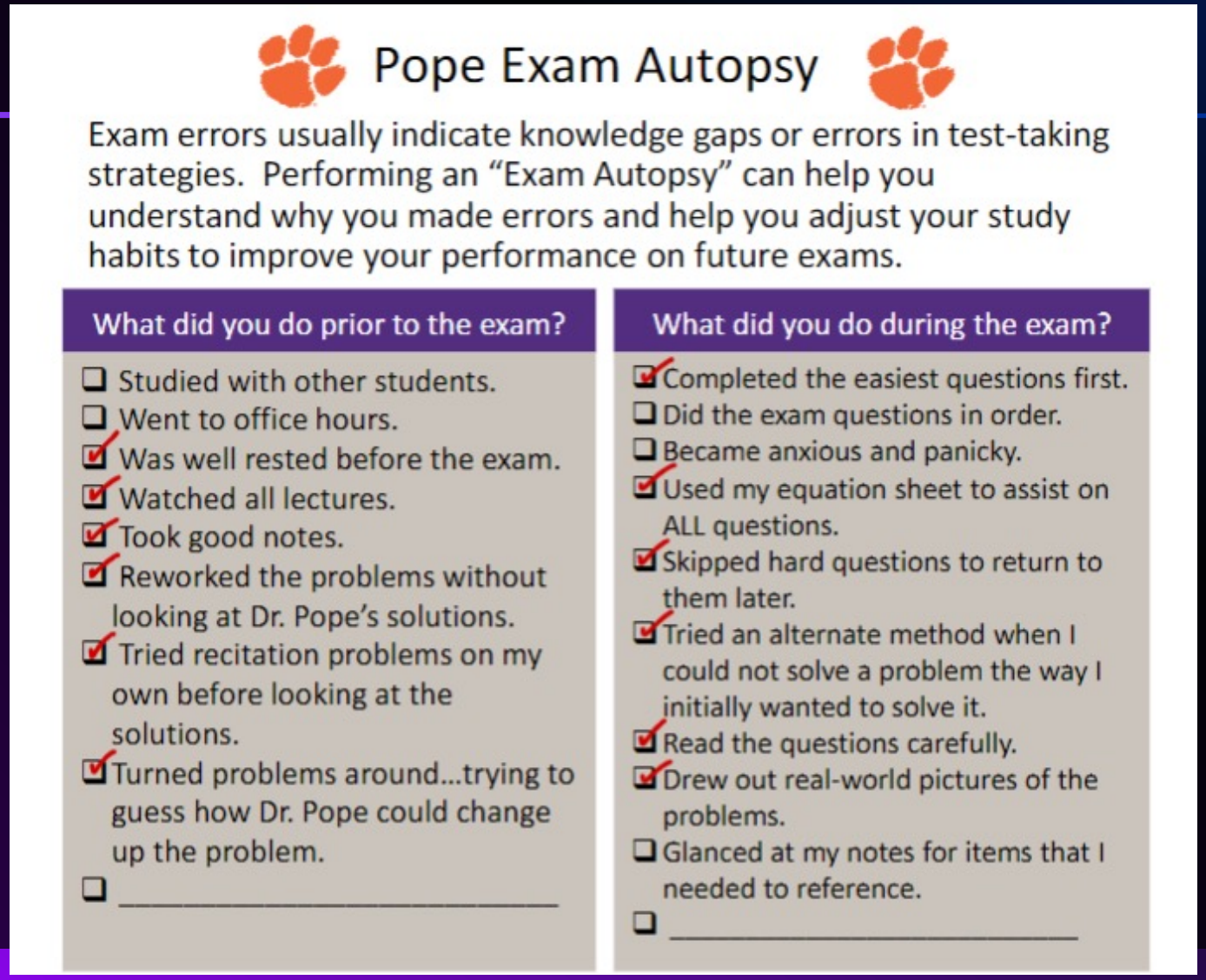
Talk to your pencil…it is relatively dense…good point, write?

- The pencil has no foundational knowledge.
- Explain each step you are taking.
- Explain WHY you are making the assumptions you are.

KEY 1: QUESTIONING ASSUMPTIONS
EXAM AUTOPSY

Students are asked to look at their behaviors prior and during the exam.

Many students assume they are studying well because they have always been successful.



Pope Exam Autopsy

Exam errors usually indicate knowledge gaps or errors in test-taking strategies. Performing an "Exam Autopsy" can help you understand why you made errors and help you adjust your study habits to improve your performance on future exams.

What did you do prior to the exam?	What did you do during the exam?
☐ Studied with other students.	☑ Completed the easiest questions first.
☐ Went to office hours.	☐ Did the exam questions in order.
☑ Was well rested before the exam.	☐ Became anxious and panicky.
☑ Watched all lectures.	☑ Used my equation sheet to assist on ALL questions.
☑ Took good notes.	☑ Skipped hard questions to return to them later.
☑ Reworked the problems without looking at Dr. Pope's solutions.	☑ Tried an alternate method when I could not solve a problem the way I initially wanted to solve it.
☑ Tried recitation problems on my own before looking at the solutions.	☑ Read the questions carefully.
☑ Turned problems around…trying to guess how Dr. Pope could change up the problem.	☑ Drew out real-world pictures of the problems.
☐ _____	☐ Glanced at my notes for items that I needed to reference.
	☐ _____

KEY 1: QUESTIONING ASSUMPTIONS
EXAM AUTOPSY

Students are asked to look at patterns for their mistakes to see what traps they are falling into.

Exam Autopsy

Directions:

1. List the questions and #'s for each item missed on the exam.
2. Place a check in the column that best describes the reason you answered the it
3. Total the number of checks in each column to determine what factors most aff
4. Review possible solutions for test errors.

	Insufficient Information								Test Anxiety				Careless Mistakes						Lack of Test Wisdom				
Test Item Missed	I did not study this concept thoroughly.	The information was not in my notes.	I studied the information but could not remember it.	I knew the main ideas but needed the details.	I knew the information but couldn't apply it.	I studied the wrong information.	Missed or did not understand the application.	Answer did not match the requested information.	I experienced a mental block.	I was tired during the test and couldn't concentrate.	I was hungry during the test and couldn't concentrate.	I panicked during the test.	I made careless mistakes – I knew the correct answer.	I changed a correct answer to a wrong one.	I did not get all available information from the problem.	I misread or misunderstood the question.	I solved for only a portion of the answer.	I did not notice a double-negative statement.	I did not eliminate obviously incorrect choices.	I did not choose the best answer choice.	I did not notice limiting words.	I made poor use of the time provided for the test.	I ran out of time/did not budget my time appropriately.
9									✓			✓	✓							✓			✓
11								✓	✓														
14			✓					✓	✓								✓					✓	
15	✓				✓				✓													✓	

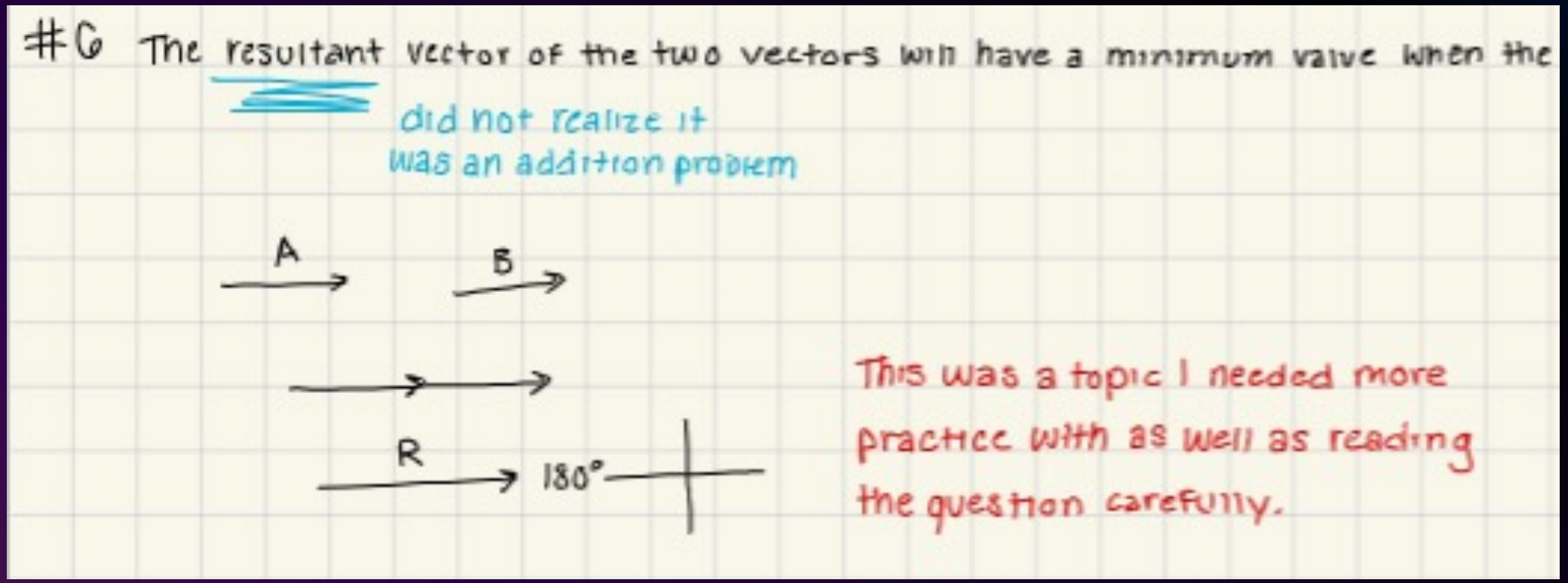
KEY 1: QUESTIONING ASSUMPTIONS
EXAM AUTOPSY

Opportunities for assistance are provided for students.

Lack of Test Wisdom	Test Anxiety/Careless Mistakes
• Attend office hours, ASC tutoring, TA office hours, join a study group. • Keep up with the material by interacting with it every day. • Clarify confusing points by asking questions in the discussion board or in the chat.	• Skip difficult questions and do those last. Let yourself calm down and become confident. • The ASC can assist you with strategies for dealing with test anxiety. • Draw out a physical picture and place useful information on that physical picture.

KEY 1: QUESTIONING ASSUMPTIONS
EXAM AUTOPSY

Students figure out what they missed and write a lesson learned.



KEY 1: QUESTIONING ASSUMPTIONS CONFRONTING BIASES

You have an incorrectly made bridge in front of you.

Make it work.

Humans tend to think about adding something before they think of taking something away — even when subtracting is the better solution.

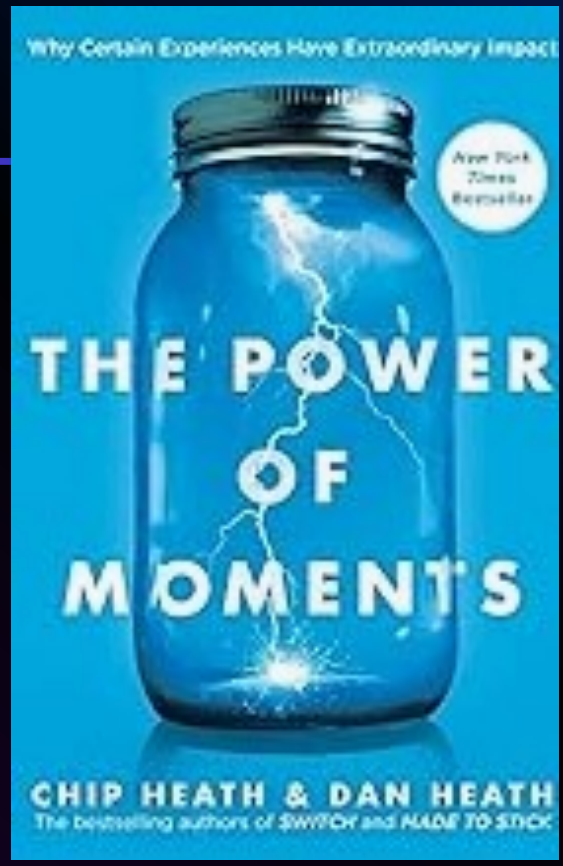
Bundell, S. (2021). Less is more: Why our brains struggle to subtract. *Nature*.

KEY 2: DEEPENING ENGAGEMENT MEMORABLE MOMENTS

“The Power of Moments: Why Certain Experiences Have Extraordinary Impact” by Chip Heath and Dan Heath talks about how brief experiences can profoundly affect us

Disney creates extraordinary experiences by creating peak moments. Disney achieves this by paying attention to details, fostering a sense of wonder, and ensuring seamless interactions with visitors.

Whether it’s a magical encounter with a character, an immersive ride, or the fireworks at the end of the day, Disney intentionally designs moments that leave a lasting impact.



KEY 2: DEEPENING ENGAGEMENT
MEMORABLE MOMENTS

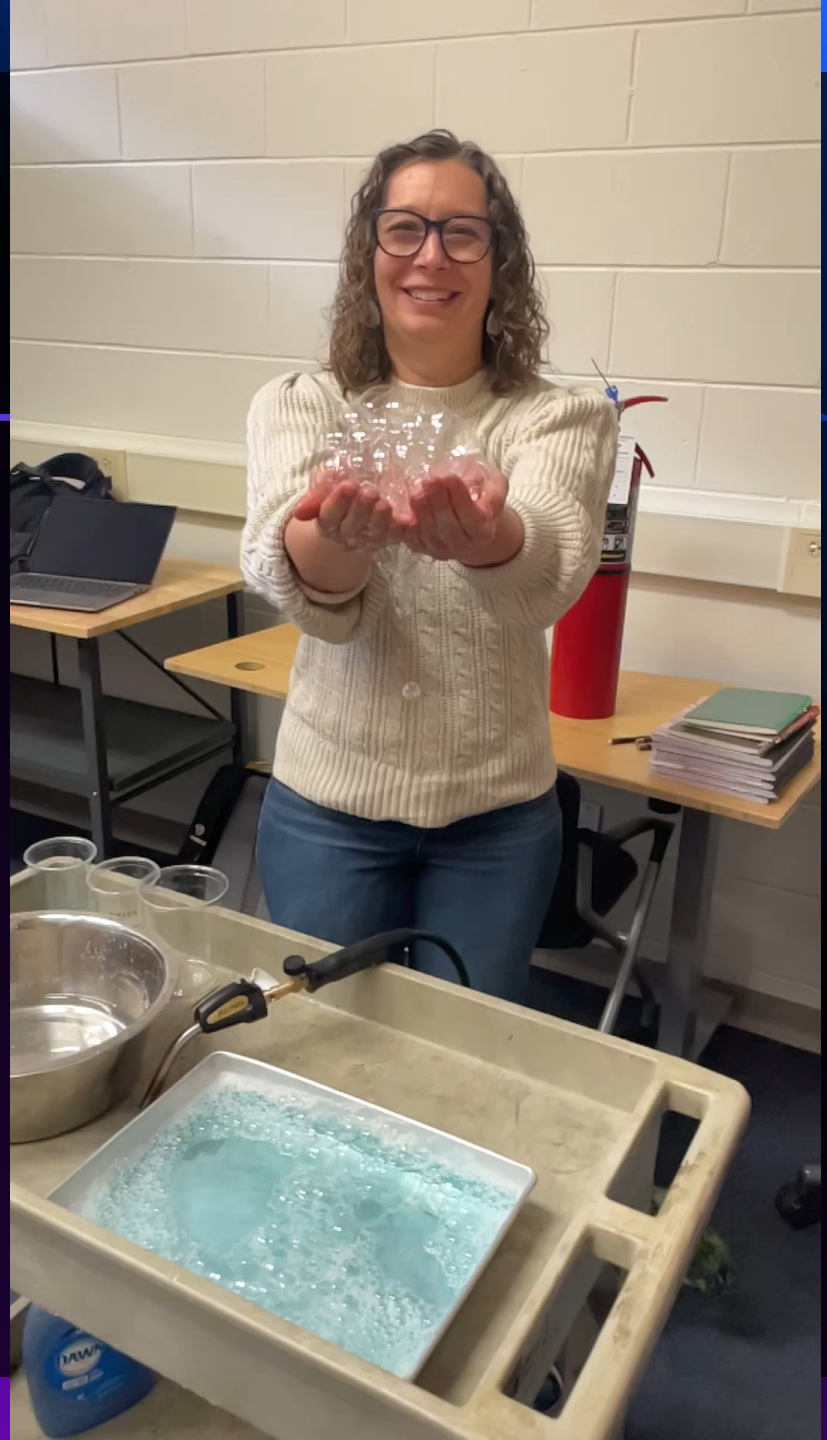
Memorable moments can help us foster critical thinking.

- Moments of Awe:
  - Awe-inspiring experiences in the classroom.
  - Awe boosts curiosity, creating engagement and therefore engaged and critical thinking.
  - Stories, demonstrations, guest speakers, games, trips.

- Engaged students are ready to learn and eager to understand what is happening.

KEY 2: DEEPENING ENGAGEMENT MEMORABLE MOMENTS

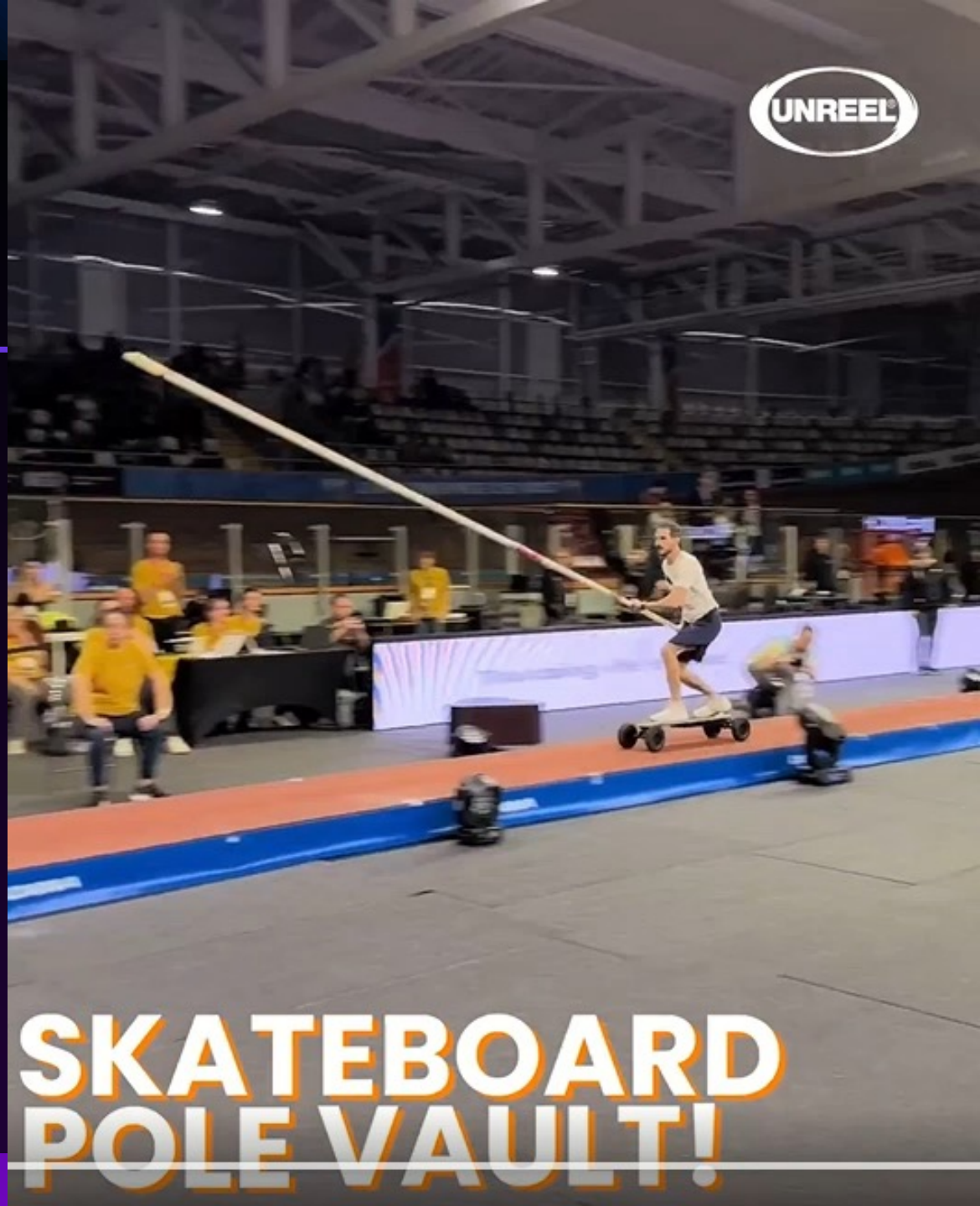
Students tend to remember that I can do this SAFELY by dipping my hands in water first, so I have a thermal expansion layer of steam to protect my hands.



KEY 2: DEEPENING ENGAGEMENT MEMORABLE MOMENTS

6.17 m max height for skateboard pole vault

6.24 m max height for standard pole vault



KEY 2: DEEPENING ENGAGEMENT
SHOW STUDENTS THERE ARE MORE LAYERS TO THE PROBLEM

Creative thinking is about taking a problem and showing that it has more layers than originally thought.

How Many Combinations Are Possible Using 6 LEGO Bricks?

Mathematician Søren Eilers wrote a computer program modeling all the possible brick combinations:

915,103,765 combinations

KEY 3: BUILDING AWARENESS

If you know the fundamentals of a discipline, you can use online resources to develop a comprehensive picture of the world around you.

- Do the reported metrics make sense?
- Is there room for ambiguity or misinterpretation?
- Do you have all the information you need?
- What else do you need to know?

LONG JUMP

Bob Beamon is a former American track and field athlete. He set the world record for the long jump in the 1968 Mexico City Olympics, an Olympic record that still holds today. With this jump, he broke the existing record by a margin of 55 cm (21 $^{2}/_{3}$ in.).

Bob Beamon's long jump in the 1968 Mexico City Olympics, 8.9 m. Data from the video footage shows that his takeoff speed was 10.02 m/s at an angle of 23.7°.

Can physics predict Beamon's actual range?

$$\%\ error = \frac{acccepted - calculated}{accepted}$$

$$R_{accepted} = 8.9\ m$$

$$R_{calculated} = \left(\frac{{v_o}^2}{g}\right)\sin 2\theta = \frac{\left(10.02\,\frac{m}{s}\right)^2}{9.8\ m/s^2}\sin 2 \cdot 23.7^o = 7.54\ m$$

$$\%\ error = \frac{acccepted - calculated}{accepted} = \frac{8.9m - 7.54m}{8.9m} = 15\%\ error$$

45° produces the longest range – why didn't he jump at this angle?

Based on approximate kinematics we predicted Beamon's jump to be 15% shorter than it was…has physics failed?

NO!!!

The range equation we used predicted Beamon's *COM* starting and ending at the same height, but he starts fully upright and ends in an extreme crouch.

Beamon is 6 ft 3 inches tall (1.91 m). Beamon's arms were slightly raised as he begins the jump so let's assume a *COM* of 1.2m at the onset and a landing *COM* at 0.5 m.

This is a change in height of 0.7m.

http://isoh.org/wp-content/uploads/2019/02/348.pdf

$$\mathrm{R} = \frac{v_o^2 sin\theta cos\theta + v_o cos\theta\sqrt{(v_o sin\theta)^2 - 2g\Delta y}}{g}$$

Assumptions:

- Beamon's takeoff speed is 10.02 m/s at an angle of 23.7°
- Beamon has an initial height of 0.7m.

Plug these values into the range equation calculator
and the new calculated range is 8.9m.

0% error.

KEY 3: BUILDING AWARENESS

Comprehensive understanding

- Breadth and depth: need to understand the problem in its entirety
- Contextual insights: understanding the background content helps in making informed decisions
- This is WHY you must take your gen ed classes!

Identifying Biases and Assumptions

- Recognize Biases of your or others – this can skew results.
- Challenge Assumptions – critical analysis help prevent erroneous conclusions

KEY 3: BUILDING AWARENESS

Enhanced Decision Making

- Informed choices – decisions should be made based on the full information available

Avoid logical fallacies

- Strengthen arguments.
- Critically evaluate all components of an argument.

FINAL TIPS AND TAKEAWAYS

- **Key 1: Questioning Assumptions**
- **Key 2: Deepening Engagement**
- **Key 3: Building Awareness**

Life is real and messy and, in an age, where everything is at our fingertips we need to be more intentional about critically assessing information.