Preparing to Teach Statistics

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Teaching Introductory Statistics and Assessing Student Learning

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Outline

- Goals for Introductory Students
- New emphases in GAISE revision: some more examples
- Ethics
- Assessment of Learning (Bloom's Taxonomy)
- Remaining a Learner yourself

Goals for Introductory Students

- Become **critical consumers**.
- Be able to apply **investigative process**.
- Produce and interpret results of **graphical displays** and **numerical summaries**.
- Recognize and explain fundamental role of **variability**.
- Recognize and explain central role of **randomness** in designing studies and drawing conclusions.

Goals for Introductory Students

- Gain experience with **statistical models**, including multivariable ones.
- Demonstrate understanding of, and ability to apply, **statistical inference** in variety of settings.
- Interpret and draw conclusions from standard output of **statistical software**.
- Demonstrate awareness of **ethical issues** associated with sound statistical practice.

New emphases in GAISE revision

Teach statistical thinking

- Teach statistics as investigative process of problem-solving and decision-making
- Give students experience with multivariable thinking

Investigative process of problem-solving and decision-making

Statistics

- Is foundation of all scientific inquiry
- Leads to data driven, objective decision making
- Is efficient and effective

Investigative process of problem-solving and decision-making

- Most real life applications require close collaboration between statistician and scientist with expert subject matter knowledge
- Requires ability to identify statistical analysis most appropriate to answer posited research question of interest
- Becoming a data detective; able to solve puzzles

Investigative process of problem-solving

Two facets of problem solving:

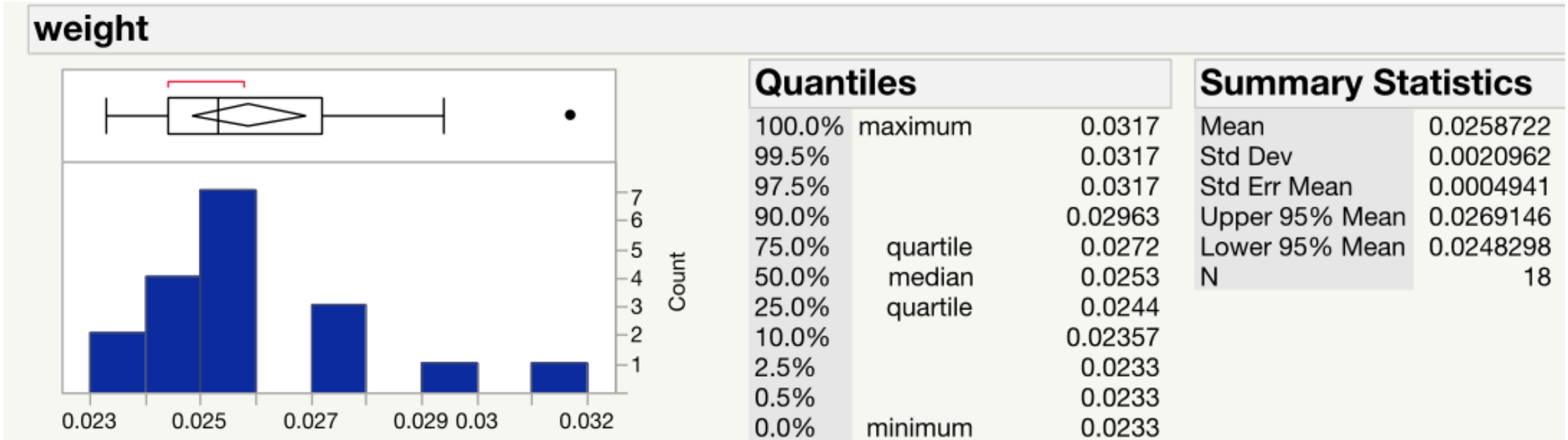
- At the level of a posited research question
- At the data level
  - Data contamination and outliers
  - Data properties

Investigative process of problem-solving

Scallops, Sampling, and the Law

- U.S. Fisheries and Wildlife Services confiscated 95% of a ship's catch (scallops) after a random sample of 18 bags (out of 11,000) resulted in an average scallop weight below the required minimum weight of 0.0278 of a pound.
- Ship's owner filed lawsuit against the federal government.
- Who is right?

Investigative process of problem-solving



- Mean, median, 3rd quartile < 0.0278, in fact 16/18 bags weighed < **0.0278** (about 89%).
- Std. deviation is 0.0021
- 95% CI for μ: (0.02483, 0.02691)

Investigative process of problem-solving

A different way of looking at the data

- 16/18 bags weighed < 0.0278 (about 89%).
- Ship's owner complains that by confiscating 95%, the government confiscated too much of the catch.

Investigative process of problem-solving

- Let p denote the proportion of all 11,000 bags weighing less than 0.0278

- 95% CI for p: (0.743706, 1.000000)

Interpretation:

- In favor of the captain or the federal government?
- Too small of a sample size?
- What can we say about the upper bound of 1?
- Adjusted 100(1-α)% CI for p by Agresti & Coull (1998)

Investigative process of problem-solving

At the data level

To Drop or Not To Drop?

- Discovery of the o-zone hole delayed for years
  - Data collected via NASA satellite
  - Observations too small (considered outliers) were automatically removed → stable o-zone layer
  - In person expedition to Antarctic resulted in lower measurements leading to discovery of o-zone hole

Investigative process of decision-making

Purchase of a SPAM filter

- Base decision on results of a 30-day free test trial
  Software will pay for itself if less than 20% of all messages are SPAM
  - How many messages should be tested?
  - Does a reduction to 19% suffice? What about a reduction to 15%?
  - Strength of evidence?
  - What about the rate of messages incorrectly labeled as SPAM?
  - What are the Type I and Type II errors?

Multivariable Thinking

- Real-life phenomena rarely explained through one-dimensional measurements
- Becomes essential when exploring relations between variables
- Helps to identify confounding factors
- Leads to increased accuracy (provided signal in the data)

Multivariable Thinking

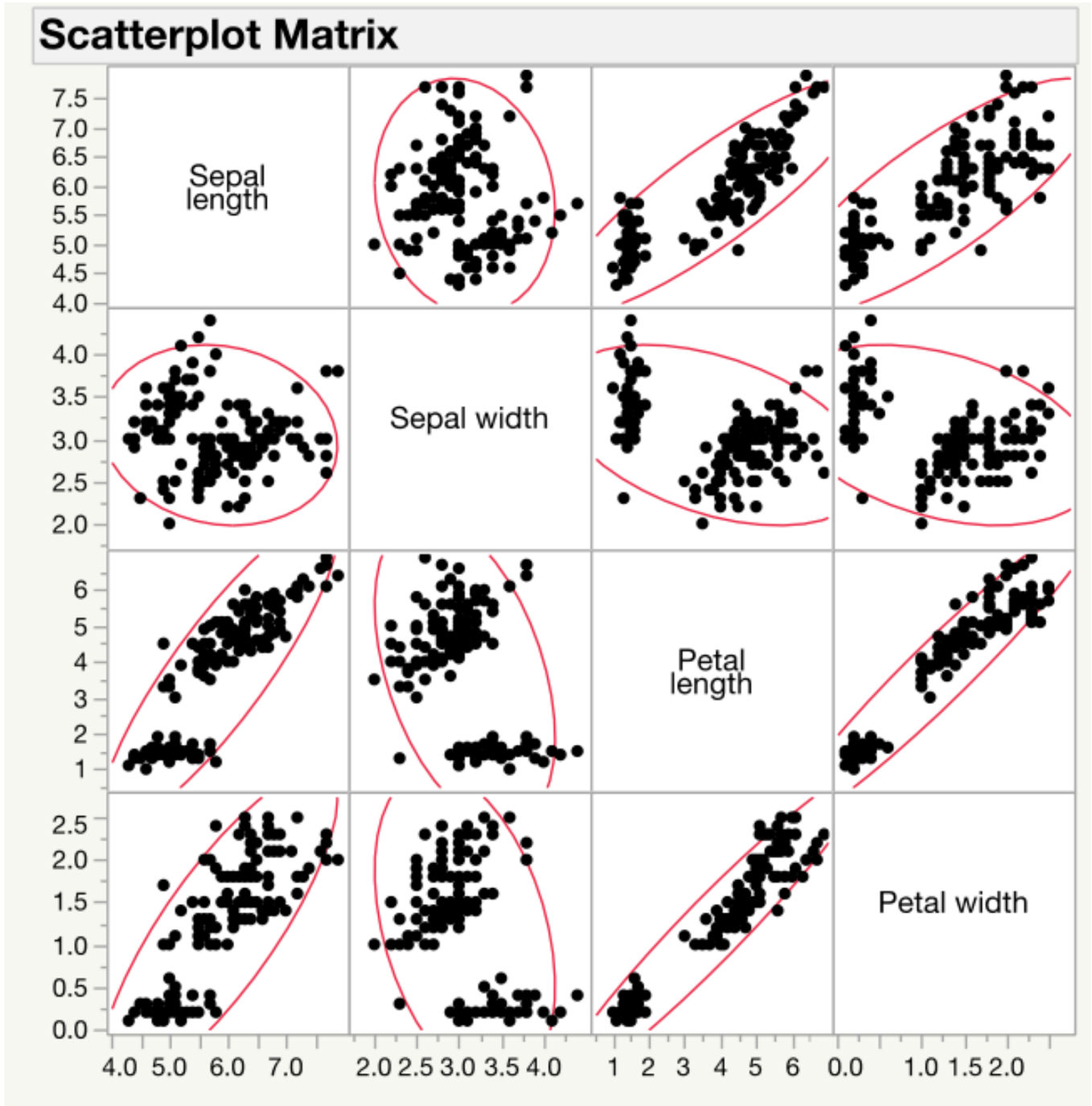
Example: IRIS data[1]

5 variables: sepal length, sepal width, petal length, petal width and species (n=150)

Correlations

	Sepal length	Sepal width	Petal length	Petal width
Sepal length	1.0000	-0.1176	0.8718	0.8179
Sepal width	-0.1176	1.0000	-0.4284	-0.3661
Petal length	0.8718	-0.4284	1.0000	0.9629
Petal width	0.8179	-0.3661	0.9629	1.0000

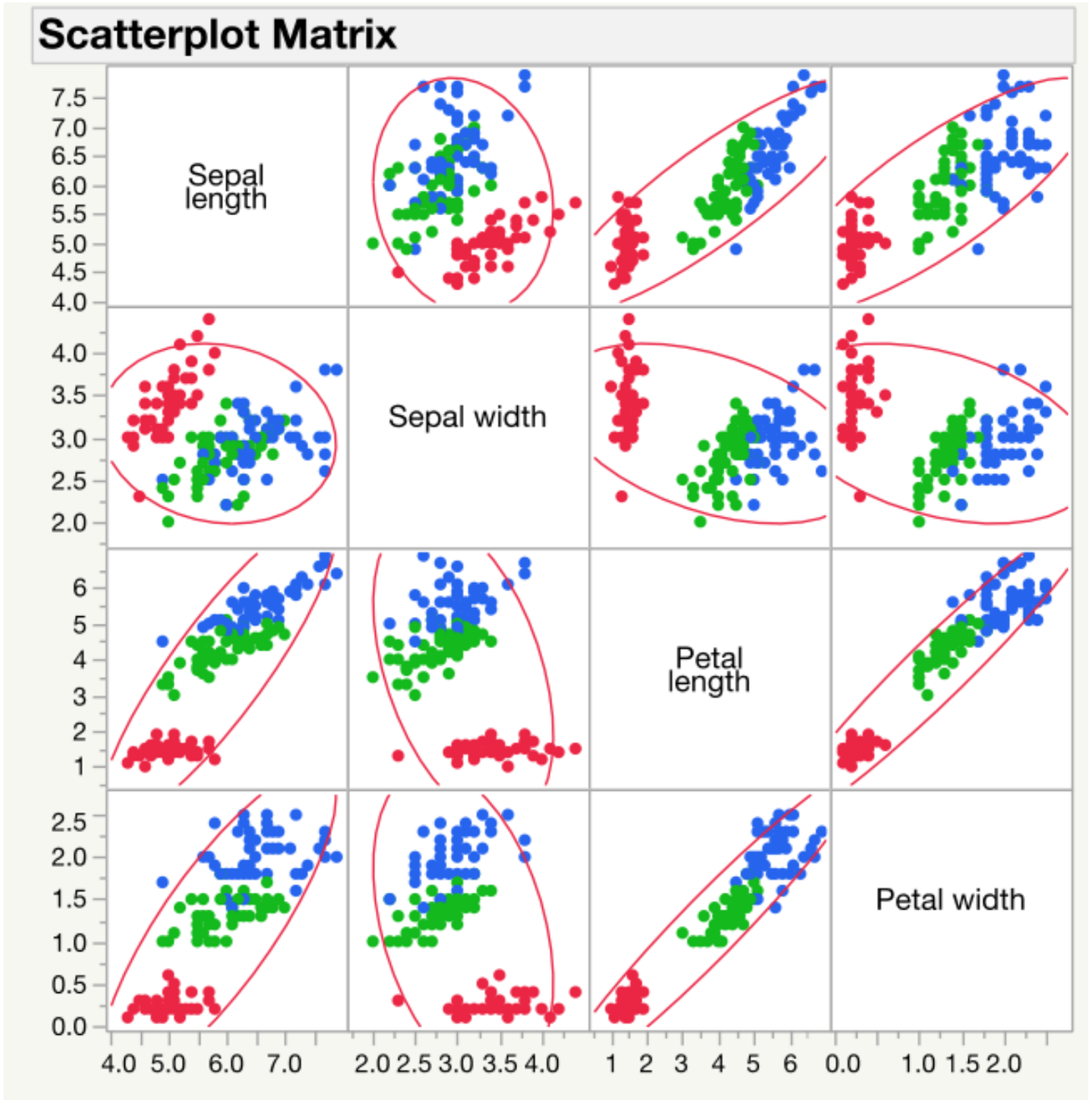
Multivariable Thinking



- Graphical display supports results given by pairwise correlations

- But note the clustering of data points

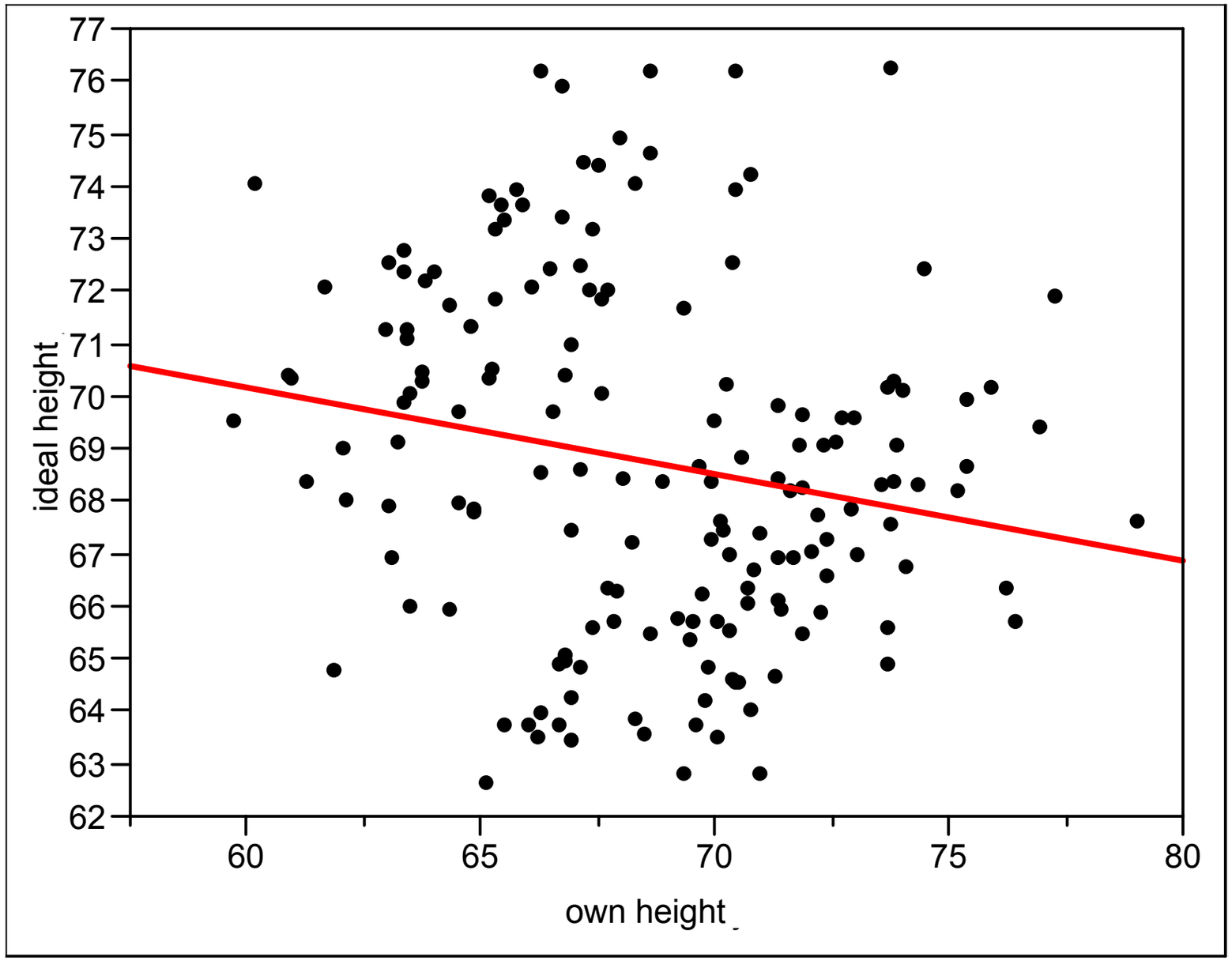
Multivariable Thinking



- Accounting for species, shows all relationships are positive

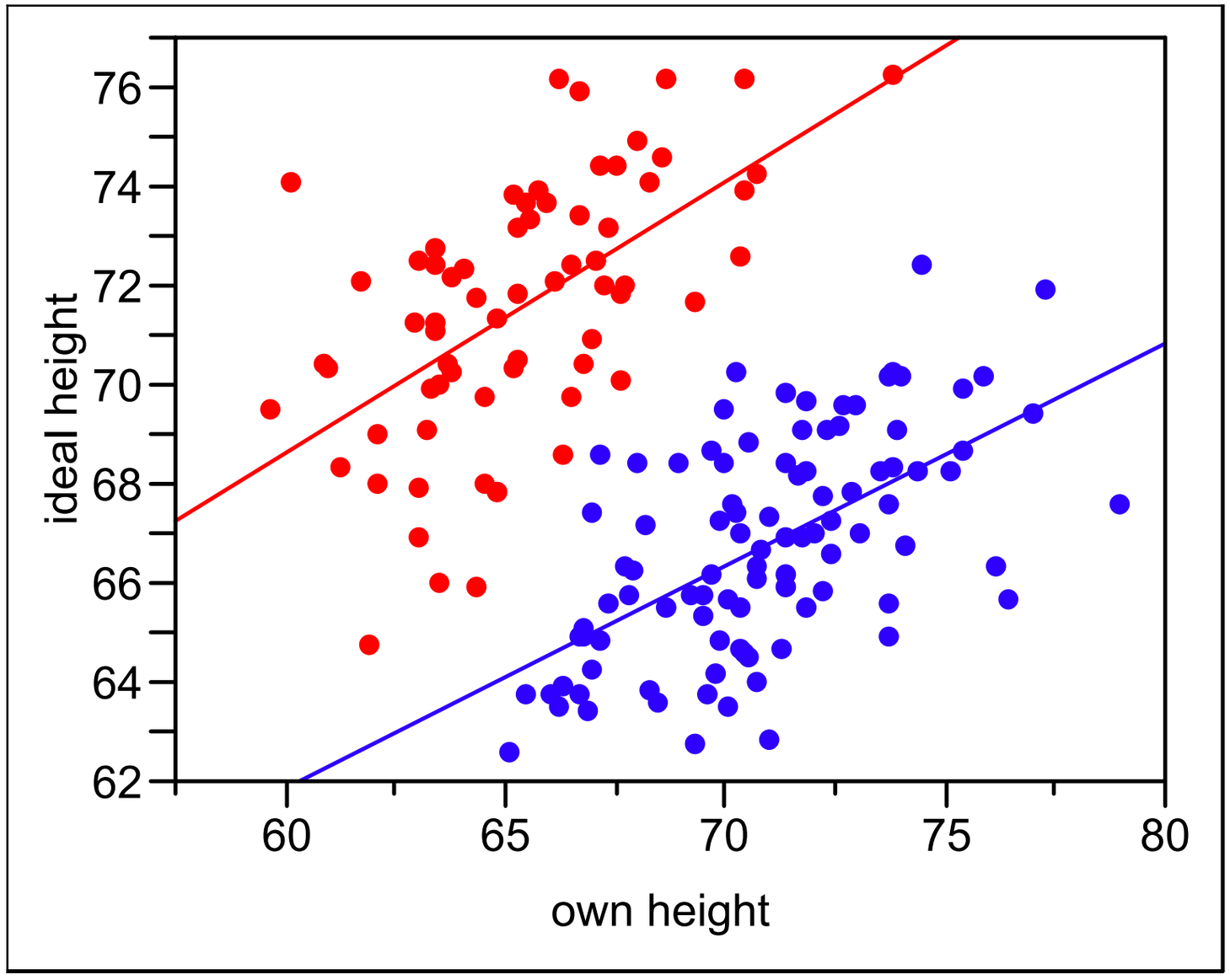
Multivariable Thinking

- What height do you consider the ideal height of your spouse?



Multivariable Thinking

- What about gender?



GAISE Appendices

- Evolution of Introductory Statistics
- Multivariable Thinking
- Activities, Datasets, and Projects
- Examples of Using Technology
- Examples of Assessment Items
- Learning Environments

Applicability of GAISE?

- To all kinds of introductory statistics courses
  - Statistical literacy vs. methods
  - All types of student majors
  - All class sizes
  - All learning environments: face-to-face, online, hybrid
  - All institution types: universities, colleges, two-year colleges, high schools
- Beyond introductory courses

Assessment of Learning

Consider

- Level you teach at vs. level you assess at

Bloom's Taxonomy

- Level you teach at vs. level you assess at
  - See **Bloom's taxonomy** for guidance:

1. Remember
2. Understand
3. Apply
4. Analyze
5. Evaluate
6. Create

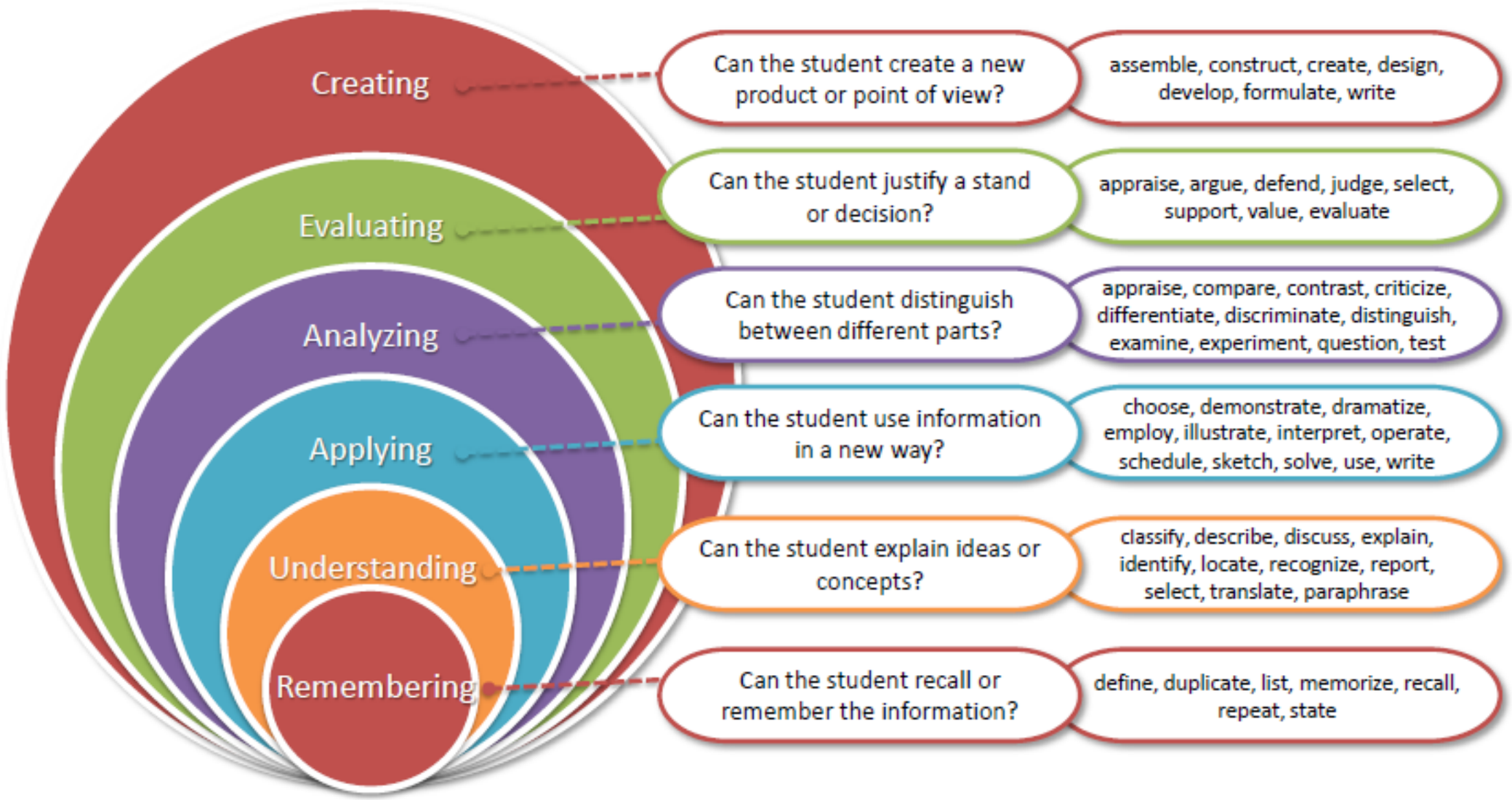
Bloom's Taxonomy — Example

Remember vs. **Understand**

- Recall basic facts & concepts
  - define, list, state…
- Explain ideas or concepts
  - describe, explain, discuss …

Assessment of Learning

Bloom's Taxonomy (Revised)



Assessment of Learning — Evaluate

University of Louisville researchers examined the process of filling plastic pouches of dry blended biscuit mix (Quality Engineering, Vol. 91, 1996).

The current fill mean of the process is set at $\mu = 406$. Operators monitor the process by randomly sampling 36 pouches each day and measuring the amount of biscuit mix in each. Consider $\bar{X}$, the mean fill amount of the sample of 36 products.

Assessment of Learning — Evaluate

Suppose that on one particular day, the operators observe $\bar{x} = 400.8$ grams and s=10.1. One of the operators believes that this indicates that the true process fill mean μ is off target, i.e. the process mean is actually different from 406 grams.

Another operator argues that $\mu = 406$, and the small value of $\bar{X}$ observed is due to random variation in the fill process.

Ethics

https://retractionwatch.com/

- data fraud, data manipulation make up a portion of the reasons for why papers got retracted
  - Diederik Stapel (Dutch Social Psychologist)
  - Andrew Wakefield (MRR vaccine & Autism)
  - Dipak Das (data fabrication and falsification)

- Last Night with John Oliver

https://www.youtube.com/watch?v=0Rnq1NpHdmw

(warn your students of adult language used in the video)

Assessment of Learning — Evaluate

Which operator do you agree with?
Evaluate the statistical evidence in your data to make a your choice.

Ethics

Turn to your partner (TTYP)
Think – Pair and Share

1. Think about the following two questions: (2-3 min)

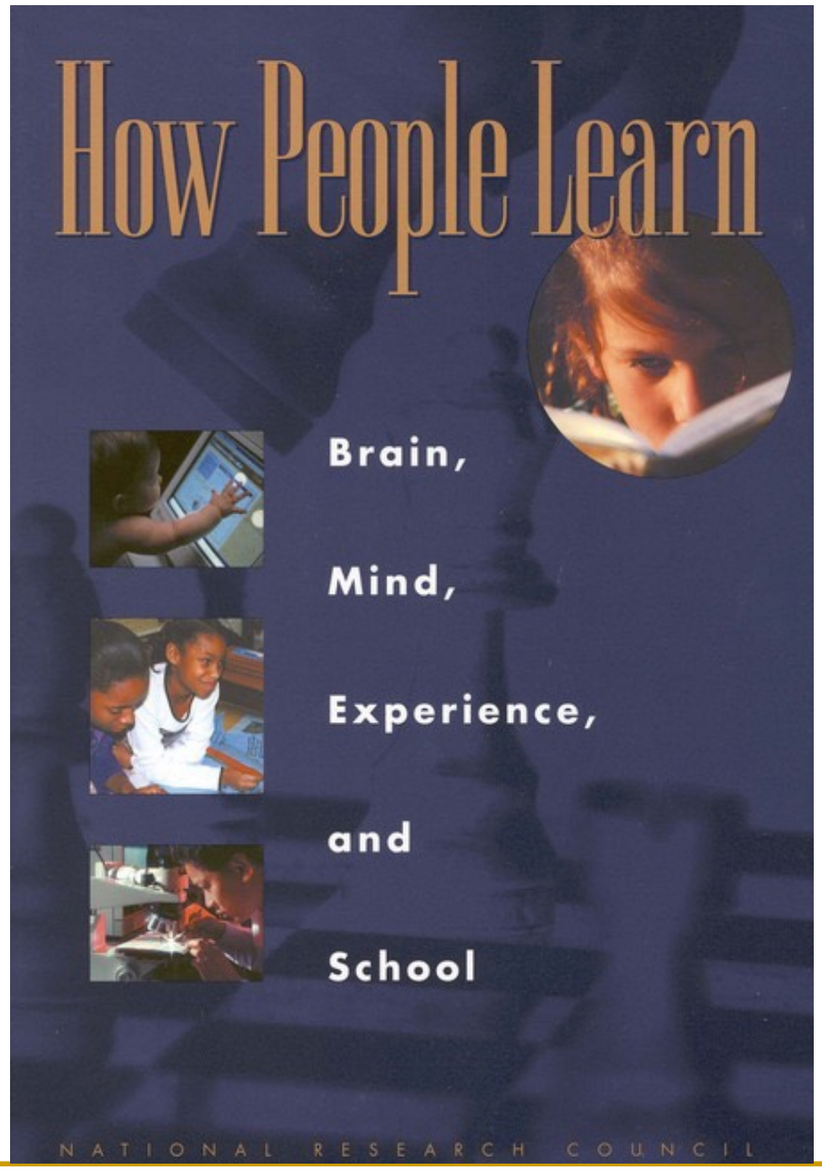
   - What do you consider an important ethical guideline(s) for statistical practice? (amstat.org)
   - What ethical principles could/should be taught in Introductory Statistics Classes?

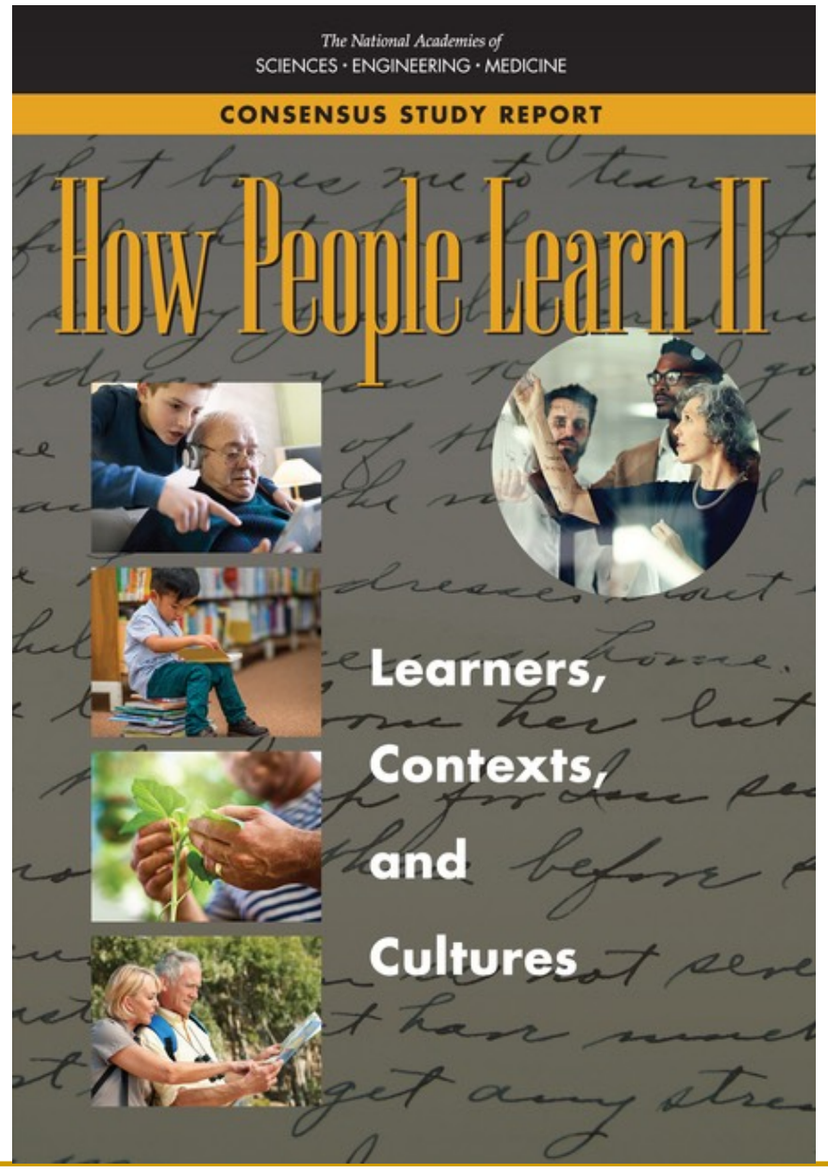
2. Turn to your partner and share your responses with each other. (4 min)

3. Share out. (3-5 min)

Remaining a Learner Yourself

National Academies of Sciences, Engineering, and Medicine (The National Academies Press)





How People Learn I — Chapters

- How experts differ from novices
- Learning and transfer
- Mind and brain
- The design of learning environments
- Effective teaching : examples in history, mathematics, and science
- Technology to support learning
- Next Steps for Research

How People Learn II — Chapters

- Context and Culture (diversity)
- Types of Learning and the Developing Brain
- Processes that Support Learning
- Knowledge and Reasoning
- Motivation to Learn
- Digital Technology
- Research Agenda

How People Learn II — Conclusion 6-1

"Motivation to learn is influenced by the multiple goals that individuals construct for themselves as a result of their life and school experiences and the sociocultural context in which learning takes place. Motivation to learn is fostered for learners of all ages when they perceive the school or learning environment is a place where they "belong" and when the environment promotes their sense of agency and purpose."

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