TEACHING STATISTICAL THINKING

2020 AMATYC Presentation
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Why?

- Many times over, we have seen surveys of employers who indicate "critical thinking" is one of the top skills needed by their employees
- I believe statistical thinking is critical thinking about statistics
- Many students, even those who have had courses with critical thinking, do not know they have that skill because it was not made explicit
- We want students to leave our courses saying, "Here is a skill I have. I can look at statistics and graphs and think more deeply about them."
- We need to be explicit with students when engaging them with critical/statistical thinking … we need to tell them this is what they are doing

GAISE (2016) Recommendations

1. Teach statistical thinking.
   - Teach statistics as an investigative process of problem-solving and decision making.
   - Give students experience with multivariable thinking.
2. Focus on conceptual understanding.
3. Integrate real data with a context and purpose.
4. Foster active learning.
5. Use technology to explore concepts and analyze data.
6. Use assessments to improve and evaluate student learning. (Page 3)

The authors indicate that "the desired result of all introductory statistics courses is to produce statistically educated students, which means that students should develop the ability to think statistically" (p. 8)

IMPACT (2018) Statements

IMPACT describes engagement through the development of student-centered learning environments that promote discourse, critical thinking, and students' self-monitoring of their learning.

"when students have the ability to apply [statistics] to real-world problems they have moved beyond observing and executing a series of isolated skills to the realm of critical thinking" (p. 24)

"A learning environment that promotes and cultivates critical thinking integrates learning activities and instructional strategies that reflect knowledge of students' skills, interests, cultural backgrounds, language proficiency, and individual needs." (p. 24)

Statistical Thinking

"We propose that it is essential to work on the development of skills that will allow students to **think critically** about statistical issues and recognize the need for data, the importance of data production, the omnipresence of variability, and the quantification and explanation of variability. **In other words, statistical thinking** – the type of thinking that statisticians use when approaching or solving statistical problems – **should be taught and emphasized in introductory courses**" (GAISE, 2016).

"Statistical thinking is a different way of thinking that is part detective, skeptical, and involves alternate takes on a problem" (Frank Harrell, 15 Sept 2020)

Chance (2002) indicated that "it seems that a definition of 'statistical thinking' includes 'what a statistician does.' These processes clearly involve, but move beyond, summarizing data, solving a particular problem, reasoning through a procedure, and explaining the conclusion. Perhaps what is unique to statistical thinking, beyond reasoning and literacy, is the **ability to see the process as a whole** (with iteration), **including 'why,'** to understand the relationship and meaning of **variation** in this process, to have the ability to explore data in ways beyond what has been prescribed in texts, and to **generate new questions** beyond those asked by the principal investigator." (p. 4)

Pfannkuch & Wild (2004) describe a variety of concepts related to statistical thinking, emphasizing that "the ability to question claims in the media and to critically evaluate such reports requires high-level thinking skills (Watson, 1997). When students are confronted with having to form a judgment on a report, they have to weigh up what they are willing to believe, what else should be done, or what should be presented to them to convince them further … [this] requires students to have … a critical disposition" (p. 35).

Critical Thinking

"A well-cultivated critical thinker:

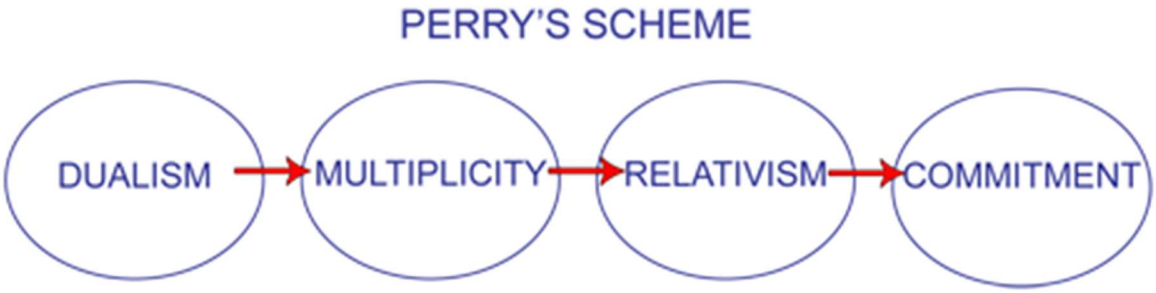
- Raises vital questions and problems, formulating them clearly and precisely
- Gathers and assesses relevant information, using abstract ideas to interpret it effectively
- Comes to well-reasoned conclusions and solutions, testing them against relevant criteria and standards

- Thinks open-mindedly within alternative systems of thought, recognizing and assessing, as needs be, their assumptions, implications, and practical consequences
- Communicates effectively with others in figuring out solutions to complex problems"

Source: http://www.criticalthinking.org/pages/our-conception-of-critical-thinking/411

"Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness" (Michael Scriven & Richard Paul, presented at the 8th Annual International Conference on Critical Thinking and Education Reform, Summer 1987)

One Scheme for Cognitive Development: Perry (1970)



Dualism: "knowledge is received, not learned … there is a correct answer" Example: This histogram tells us the true state of affairs.

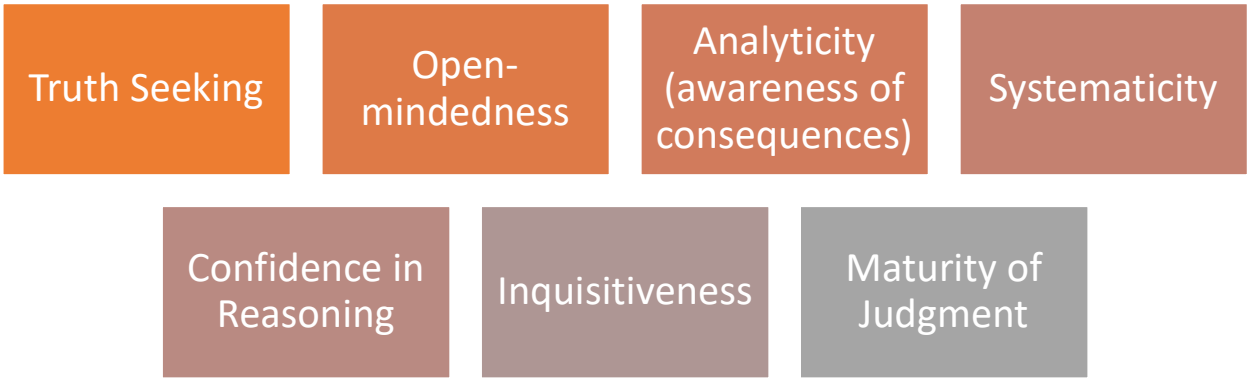
Multiplicity: "there may be more than one solution to a problem, or there may be no solution; students recognize that their opinions matter" Example: This histogram is one representation of many.

Relativism: "knowledge is seen as contextual; students evaluate viewpoints based on source and evidence" Example: Where did this data come from?

Commitment within Relativism: "integration of knowledge from other sources with personal experience and reflection" Example: Here is what I think of this histogram based on what I know about it and my own experience.

Statistical Thinking Dispositions (Wild & Pfannkuch, 1999)

Critical Thinking Dispositions (as measured by the CCTDI)



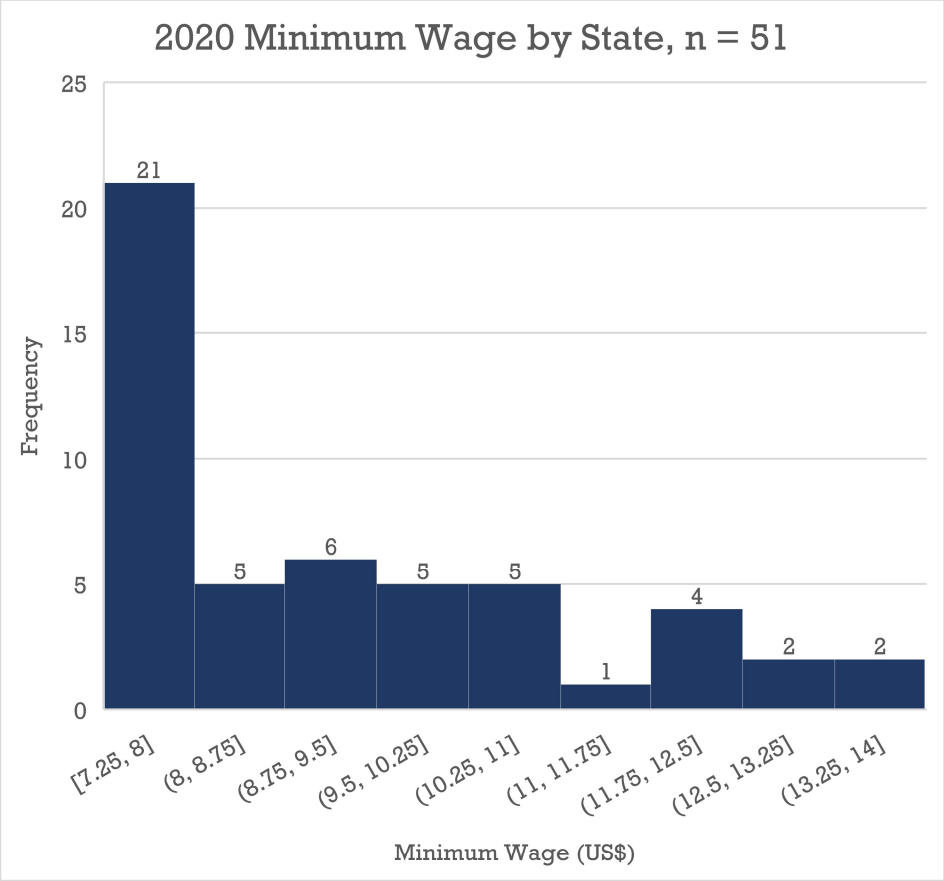
Source: https://www.insightassessment.com/article/california-critical-thinking-disposition-inventory-cctdi-2#

Sample Unit on Histograms

Step 1: Time initially spent on process for creating a histogram (students need to know how they are created in order to know how to evaluate them)

Step 2: Time spent understanding characteristics of a histogram: outliers, shape, center, and variability.

Step 3: Finish with time spent discussing what the histogram means



I first discuss the raw data and how classes can be generated to develop the histogram. I also emphasize to students that histograms are <u>not</u> plotted with individual data points – this is a common error I see.

Then we discuss outliers (none present), shape (skewed to the right), center ($8 - $8.75 range), and variability (ranges from $7.25 to $14.00).

Then I dive deeper by posing the following questions:

- What does "skewed to the right" tell us about minimum wage?
- Is the first bar on the left surprising if you know the federal minimum wage is $7.25?
- What questions does this histogram bring up for you?
- How was this data created? Is it trustworthy information?
- What would you say to a friend who wonders what minimum wage looks like in the U.S.?
- What else do you want to know about minimum wage?
- How would you go about learning more?

Modeling Statistical Thinking

- Each example we use in class or videos is a chance for instructors to say, "Here is what and how I think about this."
- This is key early in the process when students have no experience thinking critically about statistics. They are looking for "right answers" not multiple answers.
- Engage in class discussion about the possibilities and questions raised
- Eventually move to a point where students can say, "Here is what I think about this. And here is why."

Assessing Statistical Thinking

- Three Tiers (Watson, 1997):
    - 1 = Basic understanding of terminology: students creating and analyzing their own data sets
    - 2 = Embedding language and concepts in wider context: read and interpret written reports
    - 3 = Questioning of claims: confidence to challenge what they read in the media
- Possible to create any type of assessment item (objective or open-ended) that assesses statistical thinking, but to really "get to know their thought process," more open-ended items prevail.
- EXAMPLE: *For Question 11.14 you generated a graph of data based on obesity data gathered by the CDC (Centers for Disease Control and Prevention). Beyond shape, center, and spread, what does this graph tell you about obesity in the United States in 2009? How*

would you describe the 2009 obesity situation to a friend? What more would you like to know? How will you go about learning that?

The Contemporary Issues Journal (kpcrossacademy.org)

- This assessment has students selecting any topic important to them
- Seek and discuss a statistic or graph related to that topic
- Build a portfolio of such statistics and graphs throughout semester
- Reflect on what they learned

Questions I Ask:

- Summarize the information. What did you find, what is it about, how was it created, who created it, what does it say?
- List below two questions you have about this information.
- Reflect on how specific course content (e.g., a specific concept, chapter, or example) you have covered so far relates to what you found.
- Reflect on how this information relates to your personal or professional (current or future) life.

Summary

- I feel it is a commonly accepted fact that critical/statistical thinking is an important skill for students to develop
- We must be intentional about this – we must state clearly and often "you are now thinking critically and statistically"
- The culture of critical/statistical thinking needs to be built starting Day 1
- Model it, ask for it, comment on it, and assess it

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Some Resources

GAISE College Report ASA Revision Committee, "Guidelines for Assessment and Instruction in Statistics Education College Report 2016," http://www.amstat.org/education/gaise.

American Mathematical Association of Two-Year Colleges. (2018). IMPACT: Improving Mathematical Prowess and College Teaching. Memphis, TN: Author.

Victoria Woodard, Hollylynne Lee & Roger Woodard (2019): Writing Assignments to Assess Statistical Thinking, Journal of Statistics Education, 28:1. DOI: 10.1080/10691898.2019.1696257

Beth L. Chance (2002) Components of Statistical Thinking and Implications for Instruction and Assessment, Journal of Statistics Education, 10:3. DOI: 10.1080/10691898.2002.11910677

Watson, Jane M. (1997). Assessing statistical thinking using the media. In I. Gal & J. B. Garfield - (Eds.), *The Assessment Challenge in Statistics Education* (pp. 107-122). Amsterdam: IOS Press

Wild, C. & Pfannkuch, M. (1999). Statistical Thinking in Empirical Enquiry (with discussion) *International Statistical Review*, 67(3), 223-265.

Pfannkuch, M. &. Wild, C. J. (2004). Towards an understanding of statistical thinking. In D. Ben-Zvi & J. Garfield (Eds.), *The challenge of developing statistical literacy, reasoning, and thinking* (pp. 17–46.). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Also check out:

Allan Rossman's blog, "Ask Good Questions," https://askgoodquestions.blog/

Foundation for Critical Thinking, www.criticalthinking.org

K. Patricia Cross Academy, www.kpcrossacademy.org