Statistical Knowledge for Teaching
Study Design and Exploratory Data Analysis
Sample Activities
(not for distribution)

MODULE(S²)

Mathematics Of Doing, Understanding, Learning and Educating for Secondary Schools

The Mathematics Of Doing, Understand, Learning, and Educating Secondary Schools (MODULE(S2)) project is made possible through funding from the National Science Foundation IUSE (Improving Undergraduate STEM Education) multi-institutional collaborative grant #1726707 (APLU), #1726098 (University of Arizona), #1726252 (Eastern Michigan University), #1726723 (Middle Tennessee State University), #1726744 (University of Nebraska - Lincoln), and #1726804(Utah State University).

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

ACTIVITY 6: MODERN MULTIVARIATE DATA VISUALIZATIONS

The arrival of the Big Data era and expansion of technology's capabilities have ushered in a new age of modern, multivariate data visualizations. Statistical literacy in today's times means that students need to be taught to read, interpret, and question these new graphs included in media publications. No longer limited to black-and-white print on newsprint, modern newspapers are read online and include graphics that work in this new medium. In this activity, we'll consider some modern, multivariate, data visualizations and their use with secondary school students.

Why Discuss Race?

While discussing race can be uncomfortable for many of us, it is important to note that current education scholars—in particular, many of those who identify as Black or African American—advocate for an acknowledgement and discussion of race in the classroom (Love, 2019; Milner, 2012, 2017; Tatum, 2016). It might be more correct to put "race" in quotes, because we are in fact all members of the *human* race. However, racialized experiences (experiences that are connected to the way people are categorized racially by themselves or others) are an everyday part of life for many Americans, especially people of color. These experiences may be both positive and negative, and form a significant part of many people's personal identities. Race, then, is a reality in our cultural moment, and is too important to be ignored when discussing issues of equity in education.

Income Mobility Animations

A recently published study of income inequality followed 20 million children in the United States and showed how their adult incomes varied by race and gender. (Badger, Miller, Pearce, & Quealy, 2018).

Go to http://bit.ly/MobilityViz [1] and glance through the income mobility animations shown there. Once you are confident that you understand how to read the animations, scroll down to the bottom of the page, under "Create Your Own Mobility Animations." Use the pull-down menus to choose two demographic groups *you* would like to compare.

Question 6-a What is your animation telling you? Write down one or more sentences that describe what you notice. Try to get as much information as you can from the graph.

[1] or https://www.nytimes.com/interactive/2018/03/27/upshot/make-your-own-mobility-animation.html

Question 6-b Now use the pull-down menus to select White boys and girls and Black boys and girls from poor households, using their individual incomes as adults, and including kids of all mothers, including immigrants.

Screenshot of graph mid-construction

What do you notice in this graph? What is interesting to you? What do you wonder about?

You have probably heard the phrase "correlation is not causation" in conversations about statistics. In this case, this means that we cannot know from these graphs what *caused* the children from different groups to have different income distributions as adults. But you may be left wondering, "what *are* the causes of the differences in adult income between these groups?"

We will not be able to identify all of the causes in this course, and there will probably still be disagreements about what they are. However, we will start thinking about this question now, and will come back to it as we add to our knowledge throughout the course.

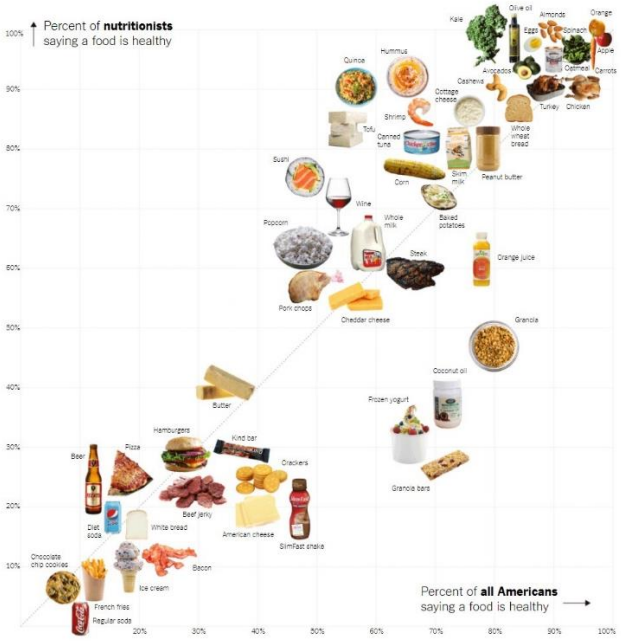
Question 6-c In small groups, use the T-chart below to brainstorm some of the possible causes of the income inequality you saw in Question 6-b. Since these will only be guesses, put question marks by them for now. Bookmark this page so that you can turn back to it later.

Separate the possible causes into two categories: causes that (according to stereotypes) originate from *within* the group that ended up less wealthy and causes that originate *outside* of the group. We have started you off with an example of each.

Possible causes (according to stereotypes) from within the group	**Possible causes from outside of the group**

Perceptions of healthy foods

View the graph at http://bit.ly/HealthyFoods00 (Quealy & Sanger-Katz, 2016).[2]



[2] Or https://static01.nyt.com/images/2017/10/05/learning/WGOITGraph10-10-17LN2/WGOITGraph10-10-17LN2-superJumbo.png

Question 6-d What do you notice? Document what you notice when reading the graph.

Question 6-e What do you wonder? Note things you are left wondering about after reading this graph, and ideas about where you could find the answers to your wonderings.

Question 6-f What's going on in this graph? What story is this graph telling? Read beyond the graph, noting what you can infer beyond what the graph shows directly.

This graph is one selected by the New York Times and the American Statistical Association for inclusion in their feature "What's Going On in This Graph?". Each graph is stripped of its caption then posted with similar prompts to those you answered for public discussion by students on the website. All graphs and related discussion are available here for your future use: http://bit.ly/WhatsGoingOn00 ("What's going on in this graph?," n.d.).[3]

Question 6-g The following are quotes from students regarding what they noticed when viewing the graph about perceptions of healthy foods. For each student remark, interpret what the student said (e.g., what is the student noticing in the graph that resulted in this remark? Is the remark correct?) then pose a response to the student that encourages them to dig deeper into the graph's story. Your response should include exactly what you would say and/or draw to the student.

i. "Popcorn and steak are roughly the same amount of healthy", said Erik.

ii. Aliyah noted "Apparently granola is not as healthy as wine."

[3] Or https://www.nytimes.com/column/whats-going-on-in-this-graph?emc=edit_ln_20171109&nl=learning-network&nlid=52022771&te=1

iii. Ji-yoo remarked "There are some foods that aren't on the line of best fit."

References

Aguirre, J., Mayfield-Ingram, K., & Martin, D. (2013). *The impact of identity in K-8 mathematics: Rethinking equity-based practices* (1st edition). Reston, VA: National Council of Teachers of Mathematics.

Badger, E., Miller, C. C., Pearce, A., & Quealy, K. (2018, March 19). Extensive data shows punishing reach of racism for Black boys. *The New York Times*. Retrieved from https://www.nytimes.com/interactive/2018/03/19/upshot/race-class-white-and-black-men.html

Badger, E., Miller, C. C., Pearce, A., & Quealy, K. (2018, March 27). Income mobility charts for girls, Asian-Americans and other groups. Or make your own. *The New York Times*. Retrieved from https://www.nytimes.com/interactive/2018/03/27/upshot/make-your-own-mobility-animation.html

Curcio, F. R. (1987). Comprehension of mathematical relationships expressed in graphs. *Journal for Research in Mathematics Education*, *18*(5), 382–393. https://doi.org/10.2307/749086

Love, B. L. (2019). *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom*. Boston: Beacon Press.

Mills, V. (2018). *Accentuating formative assessment: An essential component for system-wide equitable student outcomes.* Presentation at the 69th Annual Michigan Council of Teachers of Mathematics conference, Grand Rapids, MI, July 25, 2018.

Milner, H. R. (2012). Beyond a test score: Explaining opportunity gaps in educational practice. *Journal of Black Studies*, 43(6), 693–718.

Milner, H. R. (2017). Race, talk, opportunity gaps, and curriculum shifts in (teacher) education. *Literacy Research: Theory, Method, and Practice*, 66(1), 73–94. https://doi.org/10.1177/2381336917718804

Tatum, B. (2016). Defining racism: "Can we talk?" In P. S. Rothenberg & S. Munshi (Eds.), *Race, class, and gender in the United States: An integrated study* (Tenth edition). New York: Worth Publishers/Macmillan Learning.

Quealy, K., & Sanger-Katz, M. (2016, July 5). Is sushi 'healthy'? What about granola? Where Americans and nutritionists disagree. *The New York Times*. Retrieved from https://www.nytimes.com/interactive/2016/07/05/upshot/is-sushi-healthy-what-about-granola-where-americans-and-nutritionists-disagree.html

What's going on in this graph? (n.d.). *The New York Times*. Retrieved from https://www.nytimes.com/column/whats-going-on-in-this-graph

Additional Resources

Chetty, R., Hendren, N., Jones, M., & Porter, S. (n.d.). *Race and economic opportunity in the United States: Executive summary*. The Equality of Opportunity Project. Retrieved from http://www.equality-of-opportunity.org/assets/documents/race_summary.pdf

NCTM (2014). *Position statement on access and equity in mathematics education.* https://www.nctm.org/Standards-and-Positions/Position-Statements/Access-and-Equity-in-Mathematics-Education/

NCTM (2018). *Catalyzing change in high school mathematics: Initiating critical conversations.* Reston, VA: Author.

jenn berg, Catherine Buell, Danette Day & Rhonda Evans (2018): Meaningful Mathematics: A Social Justice Themed Introductory Statistics Course, PRIMUS, DOI: 10.1080/10511970.2018.1446478

Johnson, Jason D. "Social Justice Lessons & Mathematics" Mathematics Teaching in the Middle School, Vol. 17, No. 3 (October 2011), pp. 174-179 URL: http://www.jstor.org/stable/10.5951/mathteacmiddscho.17.3.0174

Strengthening Data Literacy Across the Curriculum, http://oceansofdata.org/projects/strengthening-data-literacy-across-curriculum-sdlc (has a special focus on statistics and equity questions)

ACTIVITY 14: RESPONDING TO STUDENT THINKING

Student Thinking when Analyzing Univariate Quantitative Data

In this activity, you will consider both middle and high school students' thinking when analyzing univariate, quantitative data.

First, you will analyze real middle school students' work on the Farmer Fred Task, which you completed for homework on Exercise 11-1. As a reminder, here is the task:

Farmer Fred Task (Houghton Mifflin Harcourt Publishing Company, 2010)

Farmer Fred has been conducting an experiment with two pens of chickens. Since they were chicks, the chickens in pen A have been eating Premium Star chicken feed, while the chickens in pen B have been eating Rapid Growth chicken feed. Help Farmer Fred decide which feed produces larger chickens.
The weights that Farmer Fred records are shown below.

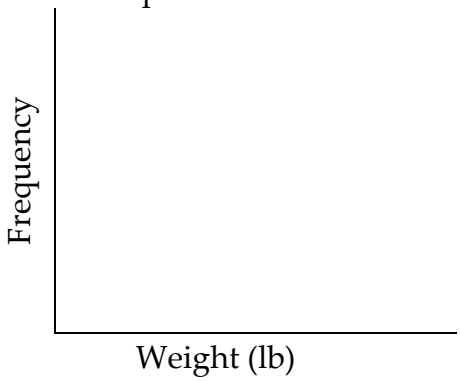
Pen A – Premium Star Chickens' Weights (lb)				
6.4	**5.2**	**7.5**	**8.3**	**5.6**
7.6	**8.1**	**7.7**	**6.2**	**6.4**
8.1	**4.8**	**5.5**	**6.6**	**6.7**
4.9	**5.1**	**8.1**	**7.9**	**7.5**

Pen B – Rapid Growth Chickens' Weights (lb)				
6.6	**5.1**	**7.7**	**8.1**	**5.7**
5.7	**4.5**	**7.4**	**6.1**	**6.3**
7.9	**4.9**	**5.6**	**6.4**	**6.8**
4.7	**5.3**	**6.0**	**8.0**	**6.6**

Make a dot plot and box plot for each chicken pen.
Make a frequency table and histogram for each chicken pen.

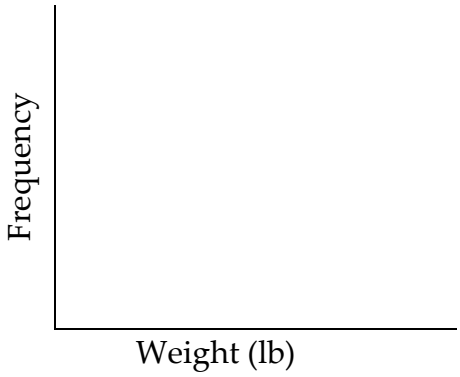
Pen A

Interval	**Frequency**
4.5 - 5.4	
5.5 – 6.4	
6.5 – 7.4	
7.5 – 8.4	



Pen B

Interval	Frequency
4.5 - 5.4	
5.5 – 6.4	
6.5 – 7.4	
7.5 – 8.4	

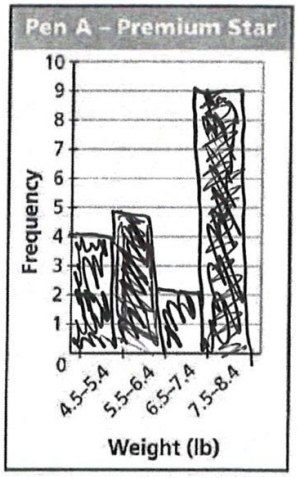


Find the mean and median weights of the chickens in each pen.
According to Farmer Fred's data, which feed produces the larger chickens? Use information from the previous problems to support your answer.

Question 14-a Two parts of José's work on this task are shown below.

D Make a frequency table and histogram of the data for pen A.

Pen A – Premium Star	
Interval	Frequency
4.5–5.4	4
5.5–6.4	5
6.5–7.4	2
7.5–8.4	9



A Find the mean and median weights of the chickens in pen A. Round to the nearest tenth if necessary.

4+5+2+9=20

2, 4, 5, 9

$4\overline{)20}$ 05

-20

00

mean = 5

median = 4.5

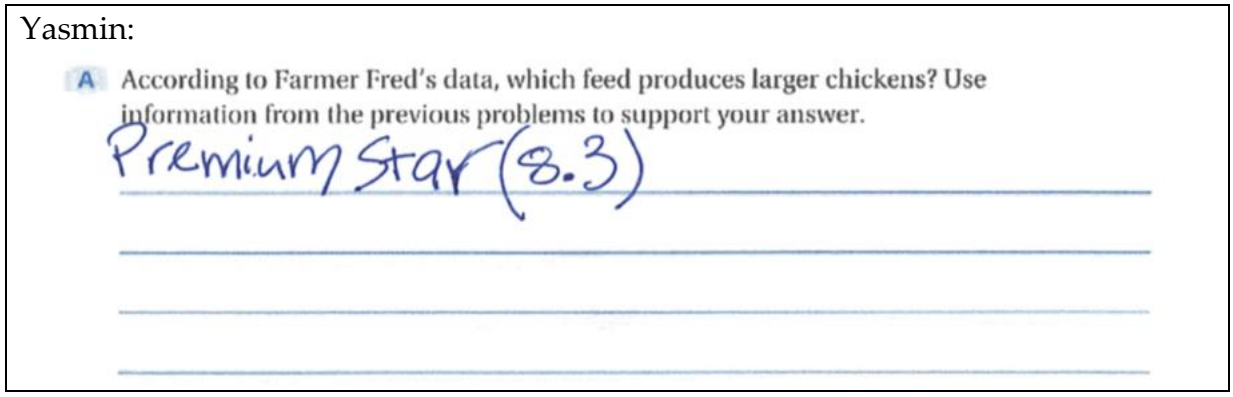
i. Name things José has done well when analyzing the data:

ii. Name things José needs to work towards understanding about analyzing univariate quantitative data.

iii. What would you write on José's paper to help him move toward a more complete understanding of how to analyze data like this?

Question 14-b Below are Yasmin and Maddie's responses to prompt (A) about which feed produces larger chickens. They typify common developing conceptions students have when comparing two data sets.

Yasmin:

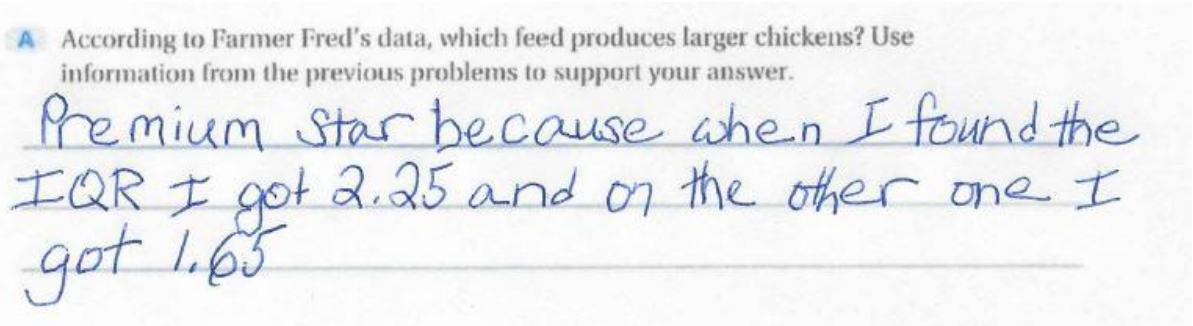

A According to Farmer Fred's data, which feed produces larger chickens? Use information from the previous problems to support your answer.

Premium Star (8.3)

i. Identify Yasmin's developing conception of how to compare two data sets.

ii. How would you respond to Yasmin to develop her sophistication in how she compares two data sets?

Maddie:



A According to Farmer Fred's data, which feed produces larger chickens? Use information from the previous problems to support your answer.

Premium star because when I found the IQR I got 2.25 and on the other one I got 1.65

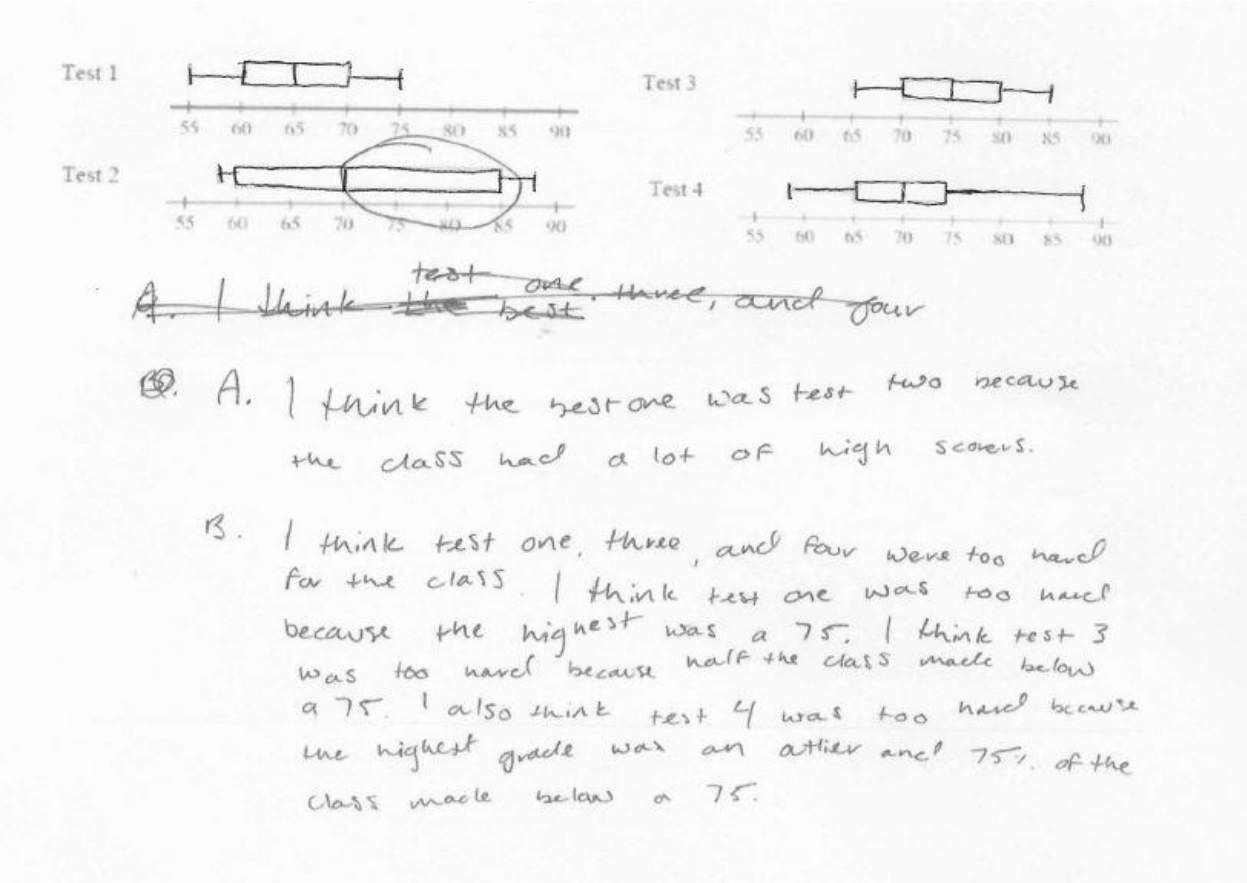
iii. For Maddie, attend to (Why did Maddie think Premium Star feed produced larger chickens?), interpret (why would she use that reasoning?) and respond to (What would you say or write to Maddie in your reply to her answer?) her thinking.

Next, we will consider the real work of high school students (not in AP Statistics) on the Test Results Task.

Question 14-c The Test Results Task and Jared's response to it is shown here:

9. Below are the results of four tests given to the same class. Using what you know about box plots, determine the following:
   - Which test do you think the class did better on and why!
   - Do you think that any of the four tests were too hard for the class?

Use specific evidence from the box plots! You must write at least 5 sentences!



i. Drawing from Jared's circling of a portion of the graph and his written answer for part (A), how can a box plot be visually confusing for a beginner?

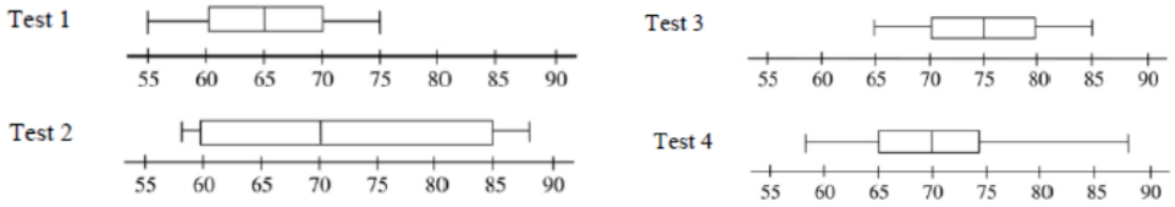
ii. In part (B), Jared says that "I also think Test 4 was too hard because the highest grade was an outlier." Assess the validity of Jared's claim that the highest grade on Test 4 was an outlier.

iii. If it is true, should that be used as the basis of an argument that Test 4 was too hard? If that is false, why might Jared have thought that?

Question 14-d Look at Graham's answer, below:

9. Below are the results of four tests given to the same class. Using what you know about box plots, determine the following:
   - Which test do you think the class did better on and why!
   - Do you think that any of the four tests were too hard for the class?

Use specific evidence from the box plots! You must write at least 5 sentences!



A. I believe that the third test was the one the class did best on because it has a higher consistency + nobody got under a 65. Meanwhile the other tests have a minimum below 65.

i. What aspect of his response demonstrates a case view of the data?

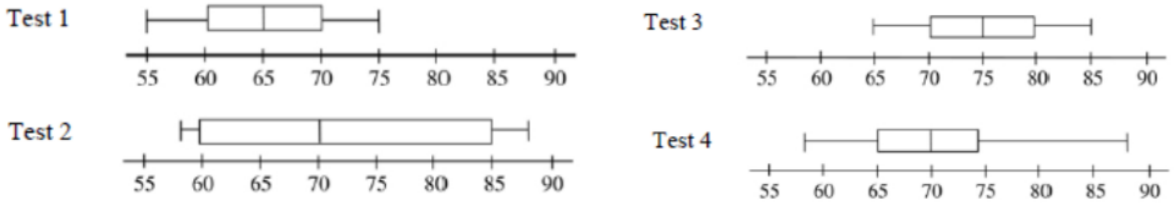
ii. Where does he show evidence that he is moving toward an aggregate view?

iii. How could you support Graham in moving towards an aggregate view?

Question 14-e Look at Candace's answer, below:

9. Below are the results of four tests given to the same class. Using what you know about box plots, determine the following:
   - Which test do you think the class did better on and why!
   - Do you think that any of the four tests were too hard for the class?

Use specific evidence from the box plots! You must write at least 5 sentences!



Test 3 because the center is 75 & the lowest grade was a 65.

Test 1 because the center is 65 & the lowest grade was a 55.

i. Is Candace's answer correct? Why or why not?

ii. What features of the distributions has Candace noted? What has she not attended to which is relevant when comparing distributions?

iii. Write a response to help Candace move further in her thinking about comparing distributions.

References

Casey, S., Lesseig, K., Monson, D., & Krupa, E. (2018). Examining preservice secondary mathematics teachers' responses to student work to solve linear equations. *Mathematics Teacher Education and Development, 20*(1), 132-153.

Groth, R. E., Butler, J., & Nelson, D. (2016). Overcoming challenges in learning probability vocabulary. *Teaching Statistics*, *38*(3), 102–107. https://doi.org/10.1111/test.12109

Houghton Mifflin Harcourt Publishing Company. (2010). *On core mathematics: Middle school grade 6*, pp. 187-190. Orlando, FL: Houghton Mifflin Harcourt.

Kaplan, J., Fisher, D. G., & Rogness, N. T. (2010). Lexical ambiguity in statistics: How students use and define the words: Association, average, confidence, random and spread. *Journal of Statistics Education*, *18*(2).

Professional Development | LOCUS. (n.d.). Retrieved September 5, 2018, from https://locus.statisticseducation.org/professional-development

Question Browser | LOCUS. (n.d.). Retrieved September 4, 2018, from https://locus.statisticseducation.org/professional-development/questions/interpret-results