Investigation 4.1
How Far Can You Jump?

Overview

This investigation focuses on students conducting a **comparative experiment** to explore the effect a fixed target will have on the distance students can jump from a starting line. Students will be randomly assigned to one of two groups. The first group will be asked to jump as far as they can from the starting line with no target in front of them. The second group will be asked to jump as far as they can, but a target (strip of tape) will be placed on the floor in front of them. Students will collect data about the distance jumped by each member of the two groups. They will display the data in a **back-to-back stemplot** or **boxplot**. Analysis of the data will include graphs and calculations of measures of center and spread.

GAISE Components

This investigation follows the four components of statistical problem solving put forth in the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report*. The four components are formulate a statistical question that can be answered with data, design and implement a plan to collect appropriate data, analyze the collected data by graphical and numerical methods, and interpret the results of the analysis in the context of the original question. This is a GAISE Level B activity.

Learning Goals

Students will be able to do the following after completing this investigation:

- Conduct an experiment to investigate a question
- Collect data and organize the results in a back-to-back stemplot (Level A) or side-by-side boxplots (Level B)
- Use the data to answer the question posed

Common Core State Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.

4. Model with mathematics.
6. Attend to precision.

Common Core State Standards Grade Level Content

6.SP.1 Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.

6.SP.2 Understand that a set of data collected to answer a statistical question has a distribution that can be described by its center, spread, and overall shape.

6.SP.3 Recognize that a measure of center for a numerical data set summarizes all its values with a single number, while a measure of variation describes how its values vary with a single number.

6.SP.4 Display numerical data in plots on a number line, including dotplots, histograms, and boxplots.

6.SP.5 Summarize numerical data sets in relation to their context, such as by the following:

a. Reporting the number of observations

b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement

c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered

d. Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered

NCTM Principles and Standards for School Mathematics

Data Analysis and Probability

Grades 6–8 Students should find, use, and interpret measures of center and spread—including mean and interquartile range—and discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stemplots, boxplots, and scatterplots.

Materials

- Masking tape
- Meter sticks
- Recording sheets (included on CD)
- Calculators

Estimated Time

1–2 days

Instructional Plan

Note: You may want to involve the physical education teacher in your school for assistance in this activity. This teacher can give suggestions regarding where to set the target line and how to collect the data.

Formulate a Statistical Question

1. Ask your students if they know what a standing long jump is. Has anyone in class done a standing long jump before? Ask one student to demonstrate a standing long jump for the class. (Several short videos demonstrating the standing long jump are available on YouTube.) Share with your students that Norwegian Arne Tvervaag holds the world record for the standing long jump. He jumped 3.71 meters (12' 2.1") on November 11, 1968.

2. Discuss with your students some reasons why one student might jump farther than another. The following are some possible reasons students may come up with: height of a student, boys might jump farther than girls, what shoes they are wearing, whether there is a prize for the longest jump.

3. After students have generated their own ideas, ask them if they think setting a target line might help a student jump farther. This investigation discusses the statistical question, "Will students jump farther if they are given a fixed target in front of them?"

Collect Appropriate Data

1. Before collecting data, there are procedures that need to be discussed with your students. It is important that your students are placed randomly into a group, that each student performs the jump in the same manner, and that the length of each jump is measured in the same way.

2. The generally accepted way to perform the standing long jump is to 1) stand with both feet up to the start line, 2) take a jump forward with both feet as far as you can, and 3) stay on your feet. **Note:** To avoid injury, this is best done on a mat or grass, instead of a hard floor.

3. The length of the jump should be measured from the start line to the part of the body that lands closest to the start line.

4. Ask students how the two groups should be formed. Students might suggest that there should be an equal number of boys and girls in each group, and some students will want to make sure the best athletes in class are spread between both groups. However, these designs do not ensure randomness. It is important that the groups are formed in a random manner. Random selection helps ensures that the two groups are similar in any attributes that might make a difference in performing the standing long jump. Discuss with your students how you might assign them randomly. One way to select students randomly is to write each of their names on an index card and then, after thoroughly mixing, draw one card at a time from the bag. The student named on the first card is assigned to the No Target group; the student named on the second card drawn is assigned to the Target group. Assignment of students continues to alternate until all the names have been drawn.

5. Set up two stations (one with No Target and one with a Target line) on the playground or in the gym where your students will perform the standing long jump. For the Target group, you may wish to ask the physical education teacher approximately how far your students will be able to jump. You want to set the target line toward the upper limit of what most students can jump. A suggestion for 12-year-olds is 200 cm from the start line.

6. Each student in the No Target group will be asked to jump as far as she/he can from the starting position marked with tape on the floor. Following the jump, with a piece of masking tape, mark the location of the student's heel, or their hand if they fall backward. The heel or hand that is closest to the starting position should be used. Measure the distance in centimeters from the starting point to the end of the jump using a meter stick or extendable tape measure. Record the measurements on the data collection sheet. Similarly, each child in the Target group will be asked to jump as far as she/he can from the starting position marked with tape on the floor. Follow the same procedures as with the No Target group for marking, measuring, and recording the jump.

7. Collect the class data. Display each of the individual student results on the board under the headings No Target group and Target group. An example is shown in Table 4.1.1.

Table 4.1.1 An Example of Data Collected from a Group of 12-Year-Olds

Length in Centimeters for No Target Group														
146	190	109	181	155	167	154	171	157	156	128	157	167	162	137
Length in Centimeters for Target Group														
199	167	147	180	185	170	171	139	154	126	179	158	181	152	

Note that the statistical design being followed is an independent groups one, in which each student participates in exactly one of the two treatments. Is this the best procedure to follow in the context of this problem? Be sure to read the extension and discuss it with your students after the experiment has been completed.

Analyze the Data

1. With the class data displayed on the board, ask your students if they think one group was able to jump farther than the other. Explain to your students that it is difficult to compare groups by just looking at the numbers; it is helpful to organize the data in a graph.

2. Have your students construct a back-to-back stemplot of the results. See Figure 4.1.1. On the board, label the No Target group on the left and the Target group on the right. The stems of the plot are the numbers 10–19, which represent 100 to 190. The "leaf" in the display represents the ones digit.

Jumping Length

No Target		Target
9	10	
	11	
8	12	6
7	13	9
6	14	7
7 6 7 4 5	15	4 8 2
2 7 7	16	7
1	17	0 1 9
1	18	0 5 1
0	19	9

Key: 16|7 represents 167 cm

Figure 4.1.1 Back-to-back stemplot comparing length of jumps for No Target group and Target group

3. Ask your students to modify their back-to-back stemplots showing the data (units digits) ordered. Figure 4.1.2 shows the back-to-back stemplot with the digits in order.

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9	10	
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Key: 16|7 represents 167 cm

Figure 4.1.2 Back-to-back stemplot comparing length of jumps for No Target group and Target group with the digits in order

4. Ask your students to compare the shapes of the two distributions from the stemplots. Note that the jump lengths in the No Target group are

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Key: 16|7 represents 167 cm

Figure 4.1.2 Back-to-back stemplot comparing length of jumps for No Target group and Target group with the digits in order

4. Ask your students to compare the shapes of the two distributions from the stemplots. Note that the jump lengths in the No Target group are

concentrated between 150–170 cm, whereas those in the Target group are spread out a bit more and appear to be higher in length. The shape of the No Target distribution is peaked, while the shape of the Target distribution is more flat, uniform. There is a gap in the No Target group, suggesting that 109 cm might be what is called an *outlier*, an atypical value. The presence of an outlier might influence the most appropriate measure of center for the data set.

5. Ordering the digits in a stemplot is helpful when finding the quartiles (note the median is the second quartile). The three quartiles are used to construct another graph—the boxplot. To construct a boxplot, have your students find the five-number summary—minimum value, first quartile (Q1) that is the median of the data points strictly below the median of the distribution, the median, the third quartile (Q3) that is the median of the data points strictly above the median of the distribution, and the maximum value. Table 4.1.2 shows the five-number summary for both the Target group and No Target group. Figure 4.1.3 shows the side-by-side boxplots for the data in this example.

Table 4.1.2 Five-Number Summary for Target and No Target Group

	Min	Max	Median	Q1	Q3
No Target Group	109	190	157	146	167
Target Group	126	199	168.5	152	180

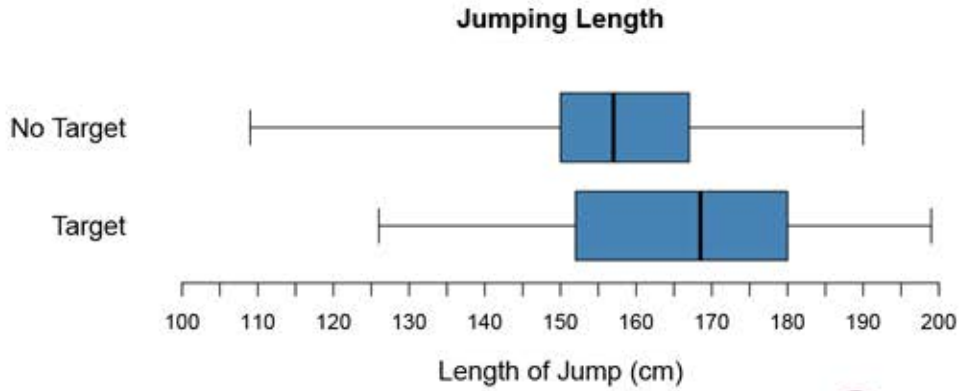

Figure 4.1.3 Side-by-side boxplots comparing length of jumps for No Target group and Target group

6. Remind your students that they are investigating whether a target helps or hinders the length of jumps. Ask your students to discuss several comparisons based on the two boxplots that will contribute to their final answer for the statistical question, "Will students jump farther if they are given a fixed target in front of them?" It is important to have your

students first discuss the meaning of the two boxplots. They should focus on comparing the medians, quartiles, and four sections of the boxplots. Note that in addition to the comparison of shapes they have made, they should note that the median for the Target group is 11.5 cm higher than that for the No Target group. That's a considerable distance. A related note to that comparison of medians is that although the first quartiles are somewhat similar (meaning that 75% of the students in each group jumped at least somewhere around 150 cm), half the students in the Target group jumped more than 168.5 cm, but half the students in the No Target group jumped no more than 157 cm, 11.5 cm shorter. Even more telling is that half the Target group jumped farther than 75% of the No Target group (Target group median is 168.5, No Target group Q3 is 167).

7. In addition to graphing and finding the median and quartiles, ask your students to find another measure of center—the mean length of the jumps. Table 4.1.3 (template available on the CD) shows the sample data and five-number summary and the mean. Discuss with your students whether to use the mean or median. The median is more robust in that it is not influenced by extreme values. The mean is influenced by extreme values, but includes all the information in the calculation. In this example, it appears that 109 is an extreme value in the No Target Group, so the median might be a better measure of center than the mean for the No Target group. Note that whichever measure is used, it should be the same for comparison purposes.

Table 4.1.3 Example Recording Sheet

Student Number	Group 1 - No Targeted Jump (cm)	Group 2 - Targeted Jump (cm)
1	146	199
2	190	167
3	109	147
4	181	180
5	155	185
6	167	170
7	154	171
8	171	139
9	157	154
10	156	126
11	128	179
12	157	158
13	167	181
14	162	152
15	137	
Summary Measures		
Mean	155.8	164.8
Median	157	168.5
Minimum	109	126
Maximum	190	199
Q1	146	152
Q3	167	180

8. Statistics is the study of variability, so a measure of spread needs to be computed to better compare the two groups. Discuss with your students that they calculated one measure of variability when they drew their boxplots, the interquartile range (IQR). The IQR = Q3 – Q1, the difference between the 1st quartile and the 3rd quartile. The IQR provides a measure of the spread of the middle 50% of the jump lengths. In the example data, the IQR of the No Target group is 21 and the IQR for the Target group is 28. This means the middle 50% of the jump lengths for the Target group has a greater spread than the middle 50% of the jump lengths for the No Target group. Discuss with your students what conclusion can be drawn about a data set concerning how spread out it is. Note that a compact data set makes its center more believable that it is reflecting the true value, whereas a widely dispersed data set makes us less sure the center is really characterizing typical performance.

   Have your students compare the two IQRs in words in the context of the data (i.e., what do the IQRs say about how spread out the jump lengths are in the No Target group compared to the Target group). Have them provide a possible contextual explanation as to why they are different. Suggestions will vary. One possibility is that in the presence of a target, people react differently. Some tense up and others push themselves beyond their normal performance.

9. Recall that from the stemplot for the No Target group, 109 was thought to be a possible outlier because it was separated from the rest of the data by a gap. The boxplot allows for a more formal determination as to whether a value should be labeled an outlier (extreme value). The procedure is to calculate what are called the upper fence and lower fence. Data points outside the fences are considered outliers (i.e., data atypical to the data set). The upper fence is Q3 + 1.5*IQR; the lower fence is Q1 – 1.5*IQR. Ask your students to calculate the fences for the No Target group. Note that the lower fence is Q1 – 1.5*IQR = 146 – 1.5*(167 – 146) = 114.5. So, it can be concluded that 109 is an outlier. The implication of this is that, in a statistical analysis of this No Target data set, it would be advisable to use the median as a measure of its center, rather than the mean.

Interpret the Results in the Context of the Original Question

1. Have your students recall the original question, "Will students jump farther if they are given a fixed target in front of them?" Ask your students to write a summary of the experiment that starts with stating an answer

to the question and then supporting their answer with their analysis. They should focus their summary on using center and spread measures, but also include a discussion about the shapes of the graphs they drew.

2. Have your students describe what they think the distribution of jumps with and without a target would be if 2nd graders performed the experiment. Do they think their conclusion they reached about the effect of a target line will be the same for the 2nd graders?

Example of 'Interpret the Results'

Note: The following is not an example of actual student work, but an example of all the parts that should be included in student work.

We conducted a comparative experiment in which some students did a standing long jump with no target in front of them and others did a standing long jump with a target 200 cm in front of them to answer the statistical question, "Will students jump farther if they are given a fixed target in front of them?" (Our gym teacher suggested 200 cm would be a good target for 12-year-olds.)

To determine which of us would be in the No Target group and which would be the Target group, we put our names in a hat. The first name randomly drawn from the hat was assigned to the No Target group. The second name drawn was assigned to the Target group. We went back and forth like that until everyone had been assigned to a group.

We measured our distances in centimeters from the starting line to where the closer heel of our shoes landed to the start line. (Everyone landed on their feet.) We tried to make sure everyone did the jump the same way to avoid introducing any sort of bias, like measurement bias, into our results. We drew two comparative graphs of our data.

Jumping Length

No Target		Target
9	10	
	11	
8	12	6
7	13	9
6	14	7
7 7 6 5 4	15	2 4 8
7 7 2	16	7
1	17	0 1 9
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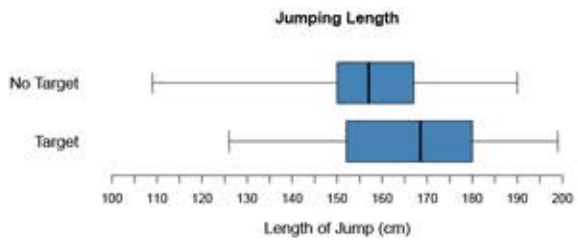


From the stemplot—except for one possible outlier (109) in the No Target group, it looked like the data sets were spread about the same. But the IQR for the No Target group is 21 and a larger 28 for the Target group, so the middle 50% of the No Target group data is more compact than for the Target group.

Actually, it's better for a data set to have a small variation because it makes us more confident about the centering value. We thought the target group should be more compact because those jumpers had something to concentrate on, but it didn't turn out that way. Regarding the 109, it is an outlier looking at the gap in the stemplot, and it is also an outlier using the Q1 - 1.5*IQR rule for the boxplot. Any value below 146 – 1.5 * (167 – 146) = 114.5 is considered an outlier.

So, did those in the Target group jump farther than the No Target group? From the stemplots, the Target group is shifted to the right compared to the No Target group. Because the No Target group has an outlier, we decided to compare the two groups with medians, rather than means. Based on medians, the answer would be yes, since the median for the Target group was 168.5 cm compared to the median for the No Target group of 157 cm. The Target group jumped a full 11.5 cm longer. In fact, half (seven students) of the Target group jumped farther than 168 cm, but only 3 of the 15 No Target group (20%) jumped that far. Having a target produces higher standing long jump distances. We were wondering if the same conclusion would be made for other age groups. Our guess is that no matter what age groups do this experiment, the results will be similar, since it seems better to have a target as a goal to achieve.

Assessment with Answers

A group of students conducted an experiment to compare the effect of where the target line is placed for the standing long jump. Target lines were placed at 100 cm and 300 cm. Table 4.1.4 shows the length of the jumps in cm for each group.

Table 4.1.4 Jump Lengths (cm) for Groups with Target of 100 cm and 300 cm

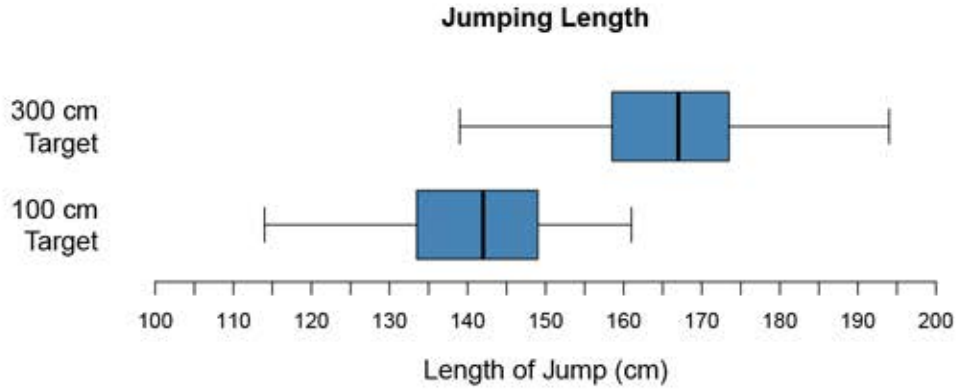
100 cm Target	149	141	161	114	116	142	129	149	138	158	145
300 cm Target	168	185	194	167	147	151	169	178	167	166	139

1. Does the distance a target line is from the start line affect the distance students jump in the standing long jump? Yes, students tended to jump farther when the target line was set at 300 cm.

2. Use words, numbers, and graphs to justify your answer by using at least one graph, a measure of center, and a measure of spread.

Summary

	100 cm target	300 cm target
Mean	140.2	166.5
Minimum	114	139
Q1	129	151
Median	142	167
Q3	149	178
Maximum	161	194
IQR	20	27



Students tended to jump farther when the target line was set at 300 cm than at 100 cm. The mean jumping distance for the 300 cm target was 166.5 cm, while the mean for the 100 cm target was 140.2. The boxplot of the 300 cm target group is shifted much further right than the 100 cm target group. About 75% of the data in the 300 cm target group are greater than about 75% of the 100 cm group.

Extensions

1. As mentioned earlier, the procedure used with all students knowing the experimental condition will no doubt bias the results, as those not assigned to the Target group may imagine a target line. To avoid this potential introduction of bias into the model, redesign the experiment using a **matched pairs** design. Each student does the standing long jump at both stations and the difference—target jump distance minus the no target jump distance—is noted between the two jumps. Your students

should be assigned randomly to which jump they do first. Your students will analyze the differences by making a dotplot, stemplot, or boxplot. If the differences are generally greater than zero, then target jump distances were better than no target distances.

2. Another measure of spread is the mean absolute deviation (MAD), found in Common Core Standard 6.SP.5c (see Investigation 3.4). Calculate the mean absolute deviation (MAD) for each group and compare the two MADs in words in the context of the experiment.

The MAD is the average of the absolute values of the distances from the group's mean. "Deviation" refers to the difference a value is from the mean. "Absolute deviation" is the absolute value of that difference. Column one of Table 4.1.5 contains the data; column two lists the data minus the mean (the deviation); and column three has the absolute value of the deviations in column two. To find the MAD, find the mean of the values in column three.

Table 4.1.5

No Target	No Target – Mean	|No Target – Mean|
146	146 - 155.8 = -9.8	9.8
190	190 - 155.8 = 34.2	34.2
109	109 - 155.8 = -46.8	46.8
181	181 - 155.8 = 25.2	25.2
155	155 - 155.8 = -0.8	0.8
167	167 - 155.8 = 11.2	11.2
154	154 - 155.8 = -1.8	1.8
171	171 - 155.8 = 15.2	15.2
157	157 - 155.8 = 1.2	1.2
156	156 - 155.8 = 0.2	0.2
128	128 - 155.8 = -27.8	27.8
157	157 - 155.8 = 1.2	1.2
167	167 - 155.8 = 11.2	11.2
162	162 - 155.8 = 6.2	6.2
137	137 - 155.8 = -18.8	18.8

The sum of the absolute deviations in this example for the no target data is the sum of the third column, namely 211.6. Dividing the sum by the number of values, 15, yields the mean of 14.1. In words, the average distance away from 155.8 cm that the 15 students jumped was 14.1 cm for the no target group.

Similarly, the MAD for the target group is 16.2 cm. So, according to the point of view of average distance data are from its mean, the target data are spread out more from their mean than the no target data are from their mean. Ask your students if that result is reflected in their boxplots. Why?

References

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