Science Olympiad Experimental Design
Using the Claim/Evidence/Reasoning in Scientific Communications

Starting in 2020, the Experimental Design event is moving towards having students use the Claim/Evidence/Reasoning (CER) framework in their reporting of findings. The CER framework provides students with the format and structure for their argument or explanation. In general, the CER framework can be broadly defined as the following:

Claim: A statement of the author's understanding of a situation. This claim should answer a question or help clarify an earlier investigation for the reader in the opinion of the author.

Evidence: Data that is used to support the claim made by the author. This data may be qualitative, quantitative, or a combination of both. There should be sufficient evidence to support the claim made by the author but not additional evidence that does not support the claim.

Reasoning: The author ties the claim together with the evidence to draw a conclusion. The claim is now supported with evidence and the author completes the connection of the evidence in support of the claim. The conclusions developed through this process are data-driven and evidence-supported statements.

The CER framework provides students with the format and structure to discuss many different parts of the investigative process, including the statistics, any outliers, data trends, errors, and the evaluation of the overall problem and hypothesis when developing the conclusion.

Example of using CER to Discuss Statistics

Consider a simple experiment using paper airplanes. A problem could be as simple as "How does the weight of the airplane affect its flight time?" Depending on the materials provided, a logical independent variable could be the weight of the paper airplane as defined by the number of paperclips attached to the airplane, while the dependent variable would be the flight time as measured by a stopwatch, measured to the nearest hundredth of a second.

Assume that the procedure calls for five repeated trials of each paper airplane, with the levels of the independent variable being defined as one paperclip, two paperclips, and three paperclips. The standard of comparison will be the flight time of the paper airplane with no weight added, as measured by a stopwatch to the nearest hundredth of a second.

Consider the following data collected.

Flight Times of Paper Airplanes with Weight Added (sec)

	No Weight (SOC)	1 Paperclip	2 Paperclips	3 Paperclips
Trial 1	3.25 sec	4.22 sec	5.14 sec	5.98 sec
Trial 2	3.82 sec	4.85 sec	5.28 sec	6.13 sec
Trial 3	3.55 sec	5.22 sec	6.33 sec	6.55 sec
Trial 4	4.58 sec	5.44 sec	3.25 sec	8.22 sec
Trial 5	1.95 sec	6.11 sec	5.58 sec	6.25 sec

The following statistics are calculated from the above data:

Statistical Values for Flight Times of Paper Airplanes with Weight Added (sec)

	No Weight (SOC)	1 Paperclip	2 Paperclips	3 Paperclips
Mean	3.43 sec	5.17 sec	5.12 sec	6.63 sec
Median	3.55 sec	5.22 sec	5.29 sec	6.25 sec
Mode (rounded)	4 sec	5 sec	5 sec or 6 sec	6 sec
Range	2.63 sec	1.89 sec	3.08 sec	2.24 sec
IQR	0.57 sec	0.59 sec	0.44 sec	0.42 sec
Standard Deviation	0.96 sec	0.70 sec	1.14 sec	0.92 sec

To use CER to discuss and interpret the statistics, the students must first examine the statistics, and then make a claim. Below are a list of possible claims that could be made:

Claim #1: The flight times were least consistent when two paperclips were added to the airplane.

Claim #2: The flight times were most consistent when only one paperclip was added to the airplane.

Claim #3: Both the mean and the median provide effective measures of the central tendency of the data.

After a claim has been made, evidence must be provided in support of the claim. This evidence will come from either the qualitative or quantitative data sections, or a combination of both. In this example, all of the evidence will come from the quantitative data section.

Evidence #1: This claim value is supported by the high value for the standard deviation among all five flights with two paperclips added to the paper airplanes. In addition, the range of values is the greatest for the flights with two paperclips when compared to all of the other levels of independent variables.

Evidence #2: This claim value is supported by the low value for the standard deviation among all five flights with only one paperclip added to the paper airplanes. In addition, the range of values is the smallest for the flights with one paperclip when compared to all of the other levels of independent variables.

Evidence #3: When looking at the differences between the mean and median values for each level of the independent variable (as well as the standard of comparison), the difference ranges from a low of only 0.05 seconds to a high of 0.38 seconds, all of which are considerably lower than not only the mean values themselves, but also the standard deviation values, representing a difference of less than one standard deviation.

After evidence has been presented, the student can complete the process by describing their reasoning and relating the claim and its supportive evidence.

Reasoning #1: Since the flights of the paper airplane with two paperclips added were the least consistent, there was likely at least one uncontrolled variable that most impacted flights of the planes with two paperclips added. The range of values was over three seconds, ranging from 3.25 seconds to 6.33 seconds, representing a nearly two times difference in the value of the dependent variable among the five flights.

Reasoning #2: Since the flights of the paper airplane with one paperclip added were the most consistent, there was likely a minimization of the uncontrolled variables at this level. The range of flight times was less than two seconds, ranging from only 4.22 seconds to 6.11 seconds, and the flights were relatively consistent as represented by the low value for the standard deviation.

Reasoning #3: Since the difference between the mean and median values was very low for all levels of the independent variable, either statistic can be used as a measure of central tendency. When compared to the standard

deviation, a measure of the variation, the difference between the mean and median for each level is considerably smaller, representing a far less than one standard deviation difference.

Example of using CER to Discuss Outliers

Claim: There were four outliers in the data observed: One outlier in the standard of comparison, two outliers in the second level, and one outlier in the third level.

Evidence: Outliers are commonly identified as being 1.5 times the IQR outside of the range from Quartile 1 to Quartile 3, creating the following ranges for each level of independent variable:

	No Weight (SOC)	1 Paperclip	2 Paperclips	3 Paperclips
Quartile 1	3.25 sec	4.85 sec	5.14 sec	6.13 sec
Quartile 3	3.82 sec	5.44 sec	5.58 sec	6.55 sec
1.5 x IQR	0.86 sec	0.89 sec	0.66 sec	0.63 sec
Lower Range	2.40 sec	3.97 sec	4.48 sec	5.5 sec
Upper Range	4.68 sec	6.33 sec	6.25 sec	7.18 sec
Outliers	1.95 sec	None	3.25 sec, 6.33 sec	8.22 sec

Reasoning: Using this common identification procedure four outliers, four outliers are identified, with two of the outliers being low outliers and two of the outliers being high outliers out of a total of 20 data points. The presence of two outliers in the second level provide further evidence of the high variability and possible uncontrolled variables present in this level, while the absence of any outliers in the first level also provides evidence of the lower variablility and better controlling of variables in this level.

Example of using CER to Discuss Data Trends

Claim: As the weight of the paper airplane increases, the average flight time of the paper airplane also increases.

Evidence: Both the mean and median flight time values clearly increases as the weight of the paper airplane increases. In addition, the slope of the line of best fit is positive (0.80 seconds/paperclip), representing a positive relationship between the independent and dependent variables.

Reasoning: This claim mirrors the hypothesis for this experiment, and the data clearly demonstrates a positive correlation between the weight of a paper airplane and its flight time. With not only the mean and median data demonstrating a positive relationship but also the slope of the line of best fit also being positive, it is clear that a dependent relationship exists between these two variables.

Example of using CER to Discuss Error

Claim: The paper airplane with two paperclips was not structurally stable and often turned corners instead of flying straight.

Evidence: A qualitative observation noted that the paper airplane with two paperclips attached seemed to fly in an unpredictable curved fashion as opposed to a relatively straight flight path for the other paper airplanes. In addition, there were two outliers identified in this level of the independent variable, the most of any level. Finally, this level had the highest variability in flight times among all the levels of the independent variable.

Reasoning: The curved flight paths of the paper airplane with two paperclips attached clearly introduced additional variability into the experiment that was not controlled well. This variability appears to have been controlled well in the other levels of the independent variable, and is likely a significant source of the high level of variability in the flight times of these airplanes, as well as the presence of two outliers.