Experimental Design Scoring Explanation
Division C
July 2023

A. Statement of Problem (2 points)

- Not a yes/no question
- The topic of the experiment is defined
- Both the independent and dependent variables are identified
- Must be clearly testable with the materials provided

A score of 2 will have all four parts listed above. A score of 1 will be missing one or two of the above items. A score of zero will be missing three or four of the above items.

B. Hypothesis (6 points)

- A statement that predicts a relationship between the independent and dependent variables
- Both variables must be included in the statement

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- The statement must take a specific direction to the prediction (it cannot be open ended)
- Both the independent and dependent variables must be included

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- A brief scientific rationale is provided for the stand taken in the hypothesis
- The scientific rationale must be relevant to the experiment

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

C. Variables (20 points)

- Independent and Dependent Variables (12 points)
    - The independent variable is correctly identified and defined in the experiment
    - There is only one independent variable
    - The independent variable is the manipulated/changed variable
    - The independent variable must be operationally defined, including units and tools of measure

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing all four above parts will receive zero points.

    - At least four levels of the independent variable are provided

A score of 4 will include at least four relevant levels of the independent variable. For less than four relevant levels of the independent variable, points will be awarded based on the number of relevant levels of the independent variable.

    - The dependent variable is correctly identified and defined in the experiment
    - There is only one dependent variable

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    - The dependent variable is the measured variable to determine the effect of the independent variable
    - The dependent variable must be operationally defined, including units and tools of measure

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing all four above parts will receive zero points.

- Controlled Variables (CV) and Constants (8 points)
    - One controlled variable is correctly identified as being controlled in the experiment (These controlled variables could be independent variables in other experiments, but are held constant in this experiment to evaluate the effect of the independent variable on the dependent variable)
    - The controlled variable identified is relevant to the experiment

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- A second controlled variable is correctly identified as being controlled in the experiment (These controlled variables could be independent variables in other experiments, but are held constant in this experiment to evaluate the effect of the independent variable on the dependent variable)
- The controlled variable identified is relevant to the experiment

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- A third controlled variable is correctly identified as being controlled in the experiment (These controlled variables could be independent variables in other experiments, but are held constant in this experiment to evaluate the effect of the independent variable on the dependent variable)

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

    - At least one constant is correctly identified in the experiment (constants are values that do not change in an experiment and could not be independent variables in other experiments)
    - The constant must be relevant to the experiment

A score of 2 will have both parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

D. Experimental Control (Standard of Comparison) (4 points)

- The Standard of Comparison (SOC) is logically identified for this specific experiment
- The SOC must be the value of the dependent variable when the independent variable is set at a specific value; usually, this value is the absence or minimization of the independent variable, depending on the specific experiment
- The value of the independent variable used to determine the SOC may be one of the levels of the independent variable listed earlier

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A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing two or more of the above items.

- A rationale must be provided for the selection of the value of the independent variable used as well as the determination of the value of the dependent variable that is used as the SOC (The SOC is also used to detect, identify, and measure any hidden or disregarded variables that may introduce additional variability into the experiment).
- The rationale must be reasonable and relevant to the experiment

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

E. Materials (4 points)

- All materials used in the experiment are provided in a list format
- This materials list must be separate from the procedure
- All materials used are quantified based on the amount of each material used in the experiment, not the amount of each material provided to use

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing two or more of the above items.

- No extra materials not used in the experiment are listed, even if they were provided for use in the experiment but were not used
- No items that were provided but not used in the experiment are listed

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

F. Procedure and Set-up Diagrams (14 points)

- Procedure is in a numbered list format
- Each step in the procedure is on a separate line, forming a list

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- Procedure is in a logical sequence
- All relevant actions completed during experiment are included in the procedure

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- Evidence of repeated trials at each level of independent variable included in procedure
- Repeated trials included repeated trials within the same level of the independent variable, not the different levels of the independent variable

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- Multiple relevant diagrams of the experiment included

A score of 2 will have at least two relevant diagrams included. A score of 1 will have one relevant diagram included. A score of zero will be missing relevant diagrams.

- Included diagrams help further explain the procedure or setup of the experiment
- All included diagrams are labeled appropriately, including titles

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A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing both of the above items.

- Procedure sufficiently detailed for another person to repeat this experiment accurately
    - No assumptions made that are not clearly expressed in procedure
    - No reasonable questions arise after reading procedure
    - Diagrams enhance overall procedure
    - Evidence of specific data, both quantitative and qualitative, that was collected during experiment
    - Evidence of how SOC was determined and measured

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing four or more of the above parts will receive zero points.

G. Qualitative Observations (12 points)

- Qualitative observations are words-based
- What parts of the procedure worked well?
- What parts of the procedure didn't work well?
- Were there any modifications to the procedure needed to obtain accurate results?
- Were there any unexpected irregularities in the procedure or data?

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing four or more of the above parts will receive zero points.

- Qualitative observations are words-based
- Were the results what was expected? Why or why not?
- Does there appear to be outliers? Any particular reason they may be present?
- Is there a trend in the data?

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing all of the above parts will receive zero points.

- Qualitative observations are words-based
- Observations should be taken throughout the entire process, including the pre-lab portion.
- Observations are taken about the data collections
- Observations are taken about the results

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing all of the above parts will receive zero points.

H. Quantitative Data - Data Table (8 points)

- Quantitative data are numbers-based
- All quantitative data, including units, must be included in a properly-labeled table
- All data measured must be included in this data table

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing two or more of the above items.

- A second data table must be included with only the relevant data to be graphed included
    - This data may include derived variables

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    - Any derived variables (including statistics) must include at least one example calculation for each derived variable

A score of 2 will have all parts listed above. A score of 1 will be missing one of the above items. A score of zero will be missing two or more of the above items.

- All tables, columns in tables, and rows in all tables are properly labeled

A score of 2 will have all parts listed above. A score of 1 will be missing a title for a table or column. A score of zero will be missing two or more titles for tables or columns.

- All data includes proper units communicated either on each data point or on row or column headings

A score of 2 will have all parts listed above. A score of 1 will be missing a unit for a data point or a column or row heading. A score of zero will be missing two or more units for data points or column or row headings.

I. Graph (12 points)

- The appropriate type of graph is used for the data
    - If the independent variable is qualitative a line graph/scatterplot should not be used
    - If the independent variable is quantitative a line graph/scatterplot is usually better than a bar graph
    - The independent variable must be represented on the x-axis of the graph and the dependent variable must be located on the y-axis of the graph

A score of 4 will have the proper type of graph used. A score of 3 will have a good, but not completely appropriate type of graph used. A score of 2 will have a graph present but not the most appropriate type. A score of 1 will have a readable graph but not an appropriate type. A score of 0 will have no graph present. Switching the x and y axes with the dependent and independent variables will result in a loss of one point.

    - Graph includes a descriptive and relevant title
    - X-axis includes proper heading
    - Y-axis includes proper heading
    - If multiple different symbols are used on the graph, a legend is provided and the legend has an appropriate and relevant title

A score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing all of the above parts will receive zero points.

    - All data include proper units either on each data point or in axes headings
    - An appropriate scale for both the dependent and independent variables must be used to best represent the data and possible correlations between variables and best utilize the space provided
    - Neither axis may have a break in the data; all axes must be continuous

A score of 4 will have all parts listed above. Every data point or heading missing a label (unit) will result in a loss of one point, up to losing all four points. An inappropriate scale that results in a too small graph or has a break in an axis will result in the loss of two points.

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J. Statistics (14 points)

- Statistics of central tendency are used
    - All statistics should be computed summarizing the data collected at one level of the independent variable, *not among different levels of the independent variable*
    - Measures of central tendency include:
        - Mean: The arithmetic average, calculated by adding up the values from the different trials at a specific level of the independent variable and dividing by the total number of trials
        - Median: The middle number, calculated by arranging the values from the different trials at a specific level of the independent variable from low to high and finding the middle value
        - Mode: The most common measurement, calculated either by taking the most commonly found measurement among the different trials at a specific level of the independent variable or rounding the values to a specified level of precision and taking the most common rounded value
        - Line of Best Fit: The equation of the regression line that minimizes the squared residuals of the data points
        - Percent Error: A measure of how close an experimental value is to the expected value (if applicable). This can also be a measure of variability.

A score of 4 will have the measure of central tendency calculated at each level of the independent variable, not among levels and have at least three of the above measures. For not properly measuring the central tendency within a level, two points will be deducted. One point will be deducted for each measure of central tendency less than three that are provided.

- At least one example calculation must be provided for each statistic calculated and units must also be included

A score of 4 will have at least one example calculation provided for each statistic calculated with appropriate units included. Every statistic provided without a sample calculation will result in a loss of one point up to a maximum of four lost points.

- All statistics should be computed summarizing the data collected at one level of the independent variable, *not among different levels of the independent variable*
- Measures of variability include:
    - Standard Deviation: A measure of how closely individual data points are arranged around the mean.
    - Interquartile Range (IQR): A measure of the variability of the middle 50% of the data.
    - Range: The difference between the highest and lowest measured values in a data set. This measure of variability is highly sensitive to outliers. The range should be included with the minimum and maximum values of the data set.

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- Frequency Table: A measure of variation for data that shows relative frequencies for each qualitative variable or bin of quantitative variable
- Histogram: A pictorial representation of a frequency table that should be accompanied by a general description of the shape, which may be left or right skewed, approximately normal, uniform, or described in another consistent manner.

A score of 4 will have the measure of variation calculated at each level of the independent variable, not among levels and have at least three of the above measures. For not properly measuring the variation within a level, two points will be deducted. One point will be deducted for each measure of variation less than three that are provided.

- All statistics calculated must be accurate

A score of 2 will have every calculation accurate. A score of 1 will have at most one calculation error. A score of zero will have two or more calculation errors.

K. Significant Figures (12 points)

- All data are reported using the proper number of significant figures for the tool of measurement used
    - *These rules do not mean that all numbers must have the same number of significant figures and/or be reported to the same level of precision; rather, each individual measurement must reflect the level of precision of the tool measurement used.*

A score of 4 will no errors in significant figures in any of the reported data. For each significant figure error in reported data, one point will be deducted up to a maximum of four points deducted.

- All numbers in all graphs and tables must follow proper significant figure rules.
    - *These rules do not mean that all numbers must have the same number of significant figures and/or be reported to the same level of precision; rather, each individual measurement must reflect the level of precision of the tool measurement used.*

A score of 4 will no errors in significant figures in the graph. For each significant figure error in the graph, one point will be deducted up to a maximum of four points deducted.

- All arithmetic operations on data to create derived variables follow rules for significant figures
    - *These rules do not mean that all numbers must have the same number of significant figures and/or be reported to the same level of precision; rather, each individual measurement must reflect the level of precision of the tool measurement used.*

A score of 4 will no errors in significant figures in any of the statistics. For each significant figure error in statistics, one point will be deducted up to a maximum of four points deducted.

L. Analysis of Claim/Evidence/Reason (CER) (18 points)

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- **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 is completed for at least one claim related to the variation in the data
    - This claim should reflect a claim about variation in the data, not a data trend for the data as a whole, as this is done later

A score of 2 for the variation claim will include a claim that meets the requirements listed above and is related to the variation of the experiment. A score of 1 for the variation claim will be missing one of the parts needed for a score of a two. A score of zero for the variation claim will be missing both parts.

A score of 2 for the variation evidence will include evidence that meets the requirements listed above and is related to the variation of the experiment. A score of 1 for the variation evidence will be missing one of the parts needed for a score of a two. A score of zero for the variation evidence will be missing both parts.

A score of 2 for the variation reasoning will include a claim that meets the requirements listed above and is related to the variation of the experiment. A score of 1 for the variation reasoning will be missing one of the parts needed for a score of a two. A score of zero for the variation reasoning will be missing both parts.

- The CER Framework is completed for at least one outlier claim
    - A quantitative measure for determining outliers should be applied
    - This measure can be used as evidence for the outlier claim
    - One common outlier measure is 1.5 times the IQR outside of the range from Q1 to Q3, but other measures can exist as well and should be defended

A score of 2 for the outlier claim will include a claim that meets the requirements listed above and is related to any outliers in the experiment. A score of 1 for the outlier claim will be missing one of the parts needed for a score of a two. A score of zero for the outlier claim will be missing both parts.

A score of 2 for the outlier evidence will include evidence that meets the requirements listed above and is related to any outliers in the experiment. A score of 1 for the outlier evidence will be missing one of the parts needed for a score of a two. A score of zero for the outlier evidence will be missing both parts.

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A score of 2 for the outlier reasoning will include a claim that meets the requirements listed above and is related to any outliers in the experiment. A score of 1 for the outlier reasoning will be missing one of the parts needed for a score of a two. A score of zero for the outlier reasoning will be missing both parts.

- The CER Framework is completed for the trend of the data
    - The claim involves the effect that the independent variable appears to have on the dependent variable, according to the data obtained in the experiment
    - Evidence can include the slope of the line of best fit or other statistics calculated from the data

A score of 2 for the data trend claim will include a claim that meets the requirements listed above and is related to the data trend in the experiment. A score of 1 for the data trend claim will be missing one of the parts needed for a score of a two. A score of zero for the data trend claim will be missing both parts.

A score of 2 for the data trend evidence will include evidence that meets the requirements listed above and is related to the data trend in the experiment. A score of 1 for the data trend evidence will be missing one of the parts needed for a score of a two. A score of zero for the data trend evidence will be missing both parts.

A score of 2 for the data trend reasoning will include reasoning that meets the requirements listed above and is related to the data trend in the experiment. A score of 1 for the data trend reasoning will be missing one of the parts needed for a score of a two. A score of zero for the data trend reasoning will be missing both parts.

M. Possible Experimental Errors (8 points)

- To obtain full credit, two specific errors must be identified and the result that each error had on the results must be discussed
    - **Random Error:** Error introduced into an experiment because of the limited precision of the instruments. Random error can be either higher or lower than the “correct” value.
    - **Procedure Error:** Error introduced into an experiment because of a known mistake done by the experimenter or because of a faulty or poor procedure.
    - **Systematic Error:** Error introduced into an experiment because of faulty equipment. Systematic errors are usually consistently higher or lower than the “correct” value.
    - For each specific error, the error should be:
        - Identified
        - Categorized by the type of error
        - Effect that the error had on the resulting data
        - Effect that the error may have had on the data trend

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For each specific error, a score of 4 will have all parts listed above. For each missing part one point will be deducted. Responses missing all of the above parts will receive zero points.

N. Conclusion (8 points)

- The hypothesis must be restated. There is no need to reword the hypothesis.

A score of 2 for restating the hypothesis will include a restated hypothesis. A score of 1 will be a hypothesis that has been changed from its original statement. A score of 0 will be no restatement of the hypothesis.

    - The CER Framework must be completed for the hypothesis
        - Did the data obtained in the experiment provide evidence in support of the hypothesis?
        - The hypothesis cannot be proven correct or incorrect, and it is not right or wrong. The evidence can either support or not support the hypothesis.

A score of 2 for the hypothesis claim will include a claim that meets the requirements listed above and is related to the hypothesis in the experiment. A score of 1 for the hypothesis claim will be missing one of the parts needed for a score of a two. A score of zero for the hypothesis claim will be missing both parts.

A score of 2 for the hypothesis evidence will include evidence that meets the requirements listed above and is related to the hypothesis in the experiment. A score of 1 for the hypothesis evidence will be missing one of the parts needed for a score of a two. A score of zero for the hypothesis evidence will be missing both parts.

A score of 2 for the hypothesis reasoning will include a claim that meets the requirements listed above and is related to the hypothesis in the experiment. A score of 1 for the hypothesis reasoning will be missing one of the parts needed for a score of a two. A score of zero for the hypothesis reasoning will be missing both parts.

O. Applications & Recommendations for Further Use (9 points)

- Provide at least three suggestions for ways to improve the particular experiment you did
- These suggestions may relate to possible ways to address the errors discussed earlier
- Generic statements of better equipment or more time to complete the experiment are not reflective earning full credit.

A score of 3 will provide at least three suggestions for ways to improve the particular experiment. A score of 2 will provide only two suggestions for ways to improve the particular experiment. A score of 1 will provide only one suggestion for a way to improve the particular experiment. A score of 0 will provide no suggestions for ways to improve the particular experiment.

- Give at least three suggestions for practical applications of the experiment

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A score of 3 will provide at least three suggestions for practical applications related to the experiment. A score of 2 will provide only two suggestions for practical applications related to the experiment. A score of 1 will provide only one practical application related to the experiment. A score of 0 will provide no practical applications related to the experiment.

- Provide at least three suggestions for future possible experiments

A score of 3 will provide at least three suggestions for future possible experiments. A score of 2 will provide only two suggestions for future possible experiments. A score of 1 will provide only one future possible experiment. A score of 0 will provide no future possible experiments.

P. Abstract (16 points)

- The abstract must be brief (usually less than 250 words) but also summarize the most important parts of the experiment.
- The abstract must be well-organized, following the report sequentially
- The abstract must be easy to follow
- The abstract must help the reader understand the summary of the research

A score of 4 will have all parts listed above. For each missing part one point will be deducted.

- The abstract must contain the statement of the problem
- The statement of the problem must be the same as it was in section A
- The abstract must contain the hypothesis
- The hypothesis must be the same as it was in section B

A score of 4 will have all parts listed above. For each missing part one point will be deducted.

- The abstract must include the research procedure
- The procedure must not be in list form and rather must be summarized including the most important parts
- The procedure must be the same procedure as was in section F
- The procedure must be in a logical sequence

A score of 4 will have all parts listed above. For each missing part one point will be deducted.

- The abstract include the major findings of the experiment, including the data trend
- The hypothesis CER must be addressed in the abstract
- The conclusion must be the same as it was in section N
- The abstract must include a discussion on errors and the effect they may have had on the conclusions

A score of 4 will have all parts listed above. For each missing part one point will be deducted.

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