Sample E

Criteria	Teachers' mark
Personal Engagement	1
Exploration	3
Analysis	3
Evaluation	2
Communication	4
Total	13

Bow Strength at Various Distances by test of Arrow Penetration.

This is a practical investigation into the relationship between an arrow's penetration depth and the distance at which it was shot from. I will shoot the arrow(s) at various distances ranging from 5 to 25 yards in increments of 5 yards and that will be my independent variable and the depth of the arrow measured in inches into the target will be the dependent variable. Four trials at each distance will be conducted to ensure accurate data.

Research Question

How does the distance at which the arrows are shot from affect the penetration depth of the arrows into the target?

Below is a list of variables in my experiment.

Variables

Name	Type (I,C,D)	Why type of variable?	How its measured
Distance arrow is shot from	Independent	To determine what affect this has on the penetration of the arrow	In yards ranging from 5 to 25 in increments of 5 yards
Penetration of arrow into target	Dependent	To determine how this is affected by the distance the arrow was shot from	Marking arrow with visible color before extracting from target and measuring in inches distance from tip of arrow to mark on arrow shaft.
Length, brand, weight, and diameter of arrow and field point.	Controlled	By using the same dimensions and weight we can count on more accurate data	Not applicable
Bow arrows are shot from	Controlled	I will be using the same bow for each trial	Not applicable
Testing environment	Controlled	By using the same environment we don't have to worry about different conditions affecting	Not applicable

		data.	
Rangefinder	Controlled	By using the same rangefinder we can guarantee consistent distances	Not applicable

Hypothesis

As I increase the distance I am predicting that the arrow penetration depth decrease, meaning that the distance and the arrow penetration depth are inversely proportional.

Design Aspect2

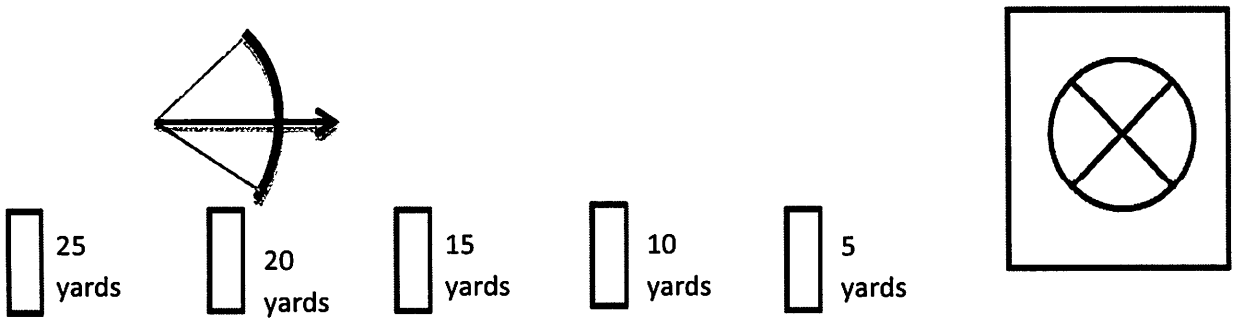
Materials

- Four identical arrows
- Target
- Bow
- Rangefinder
- Vibrant colored marker
- Tape measure (inches and centimeters)
- Vibrant colored spray paint

To measure the depth that the arrows penetrated the target, I marked the arrow with my vibrant colored marker, then extracted the arrow and measured from the tip of the front of the arrow to the bottom of the mark that I made on the shaft of the arrow.

To measure my independent variable I used my rangefinder and a can of vibrant colored spray paint, I ranged my target to where I was standing 5 yards from it, marked the ground, ranged to where I was 10 yards from it and marked the ground with my spray paint, and repeated the process for all my increments (5, 10, 15, 20, and 25 yards)

In order to control my variables I was sure to stay consistent with the equipment I used, and kept my shot placement in the same place in order to make sure that the arrows did not hit a spot on the target that was particularly weak or firmer than the rest.



Method

1. Begin by placing your target down, and using your rangefinder to find 5 yards from the target. Once found mark with the spray paint the ground and repeat process for 10, 15, 20, and 25 yards.
2. Start at 5 yards, shoot the target, and mark on the arrow as close as you can get to the target without moving the arrow at all.
3. Then extract the arrow and be careful to not smudge or wipe off the mark you made on the arrow shaft.
4. Measure from the point of the field tip to the bottom of the mark you made, and record data.
5. Wait a minute or two in between each shot in order to let any heat created in the target from the friction disperse and cool.
6. Repeat steps 2-5 four times for distances 5, 10, 15, 20, and 25 yards.

Design Aspect 3

The experiment was repeated four times for each distance shot from, 5, 10, 15, 20, and 25 yards. I measured the distance from where my front foot was standing while I shot and not from the closest point on my bow to the target because I think that that would have been too dangerous of a measurement to attempt.

Data Collection and Processing 1

Raw Data

Below is table including all my raw data that I found while conducting my experiment. In my table you can see the data of four separate trials conducted from different distances ranging from 5 to 25 yards.

Depth in inches arrow has from being shot at various distances.				
Distance(yards)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**
5	14.25	14.375	13.625	13.875
10	17.125	16.375	16.625	17.375
15	17.625	18	17.875	18.063
20	17.125	16.75	17	16.875
25	15.188	14.625	15.313	14.875

On some trials where I would not hit the target in the same area as the other arrows I noticed that my data would vary greatly so I excluded those trials from my overall data.

Data Collection and Processing 2

Depth in inches arrow has from being shot at various distances.	
Distance (yards)	**AVG Depth (in)**
5	14.031
10	16.875
15	17.891
20	16.938
25	15.000

To find the average depth each arrow penetrated the target I used the equation: Average depth of the arrow from X yards = $(Trial_1 + Trial_2 + Trial_3 + Trial_4)/4$

Example calculation

Average depth of the arrow from 5 yards = (14.250 + 14.375 + 13.625 + 13.875)/4 = 14.031inches

Uncertainties

Because we are not conducting this experiment in a perfect world there is some error in my experiment. To calculate uncertainty we first need to find the range and to do that we subtract the lowest value from the greatest value, and once we have that divide it by two. We use the equation: Uncertainty of depth of arrow from distance X = range/2

Example calculation

Range of depth of arrow from distance of 5 yards = (14.375 – 13.625) = 0.75 inch

Uncertainty of depth of arrow from distance of 5 yards = (0.75/2) = ± 0.375 inch

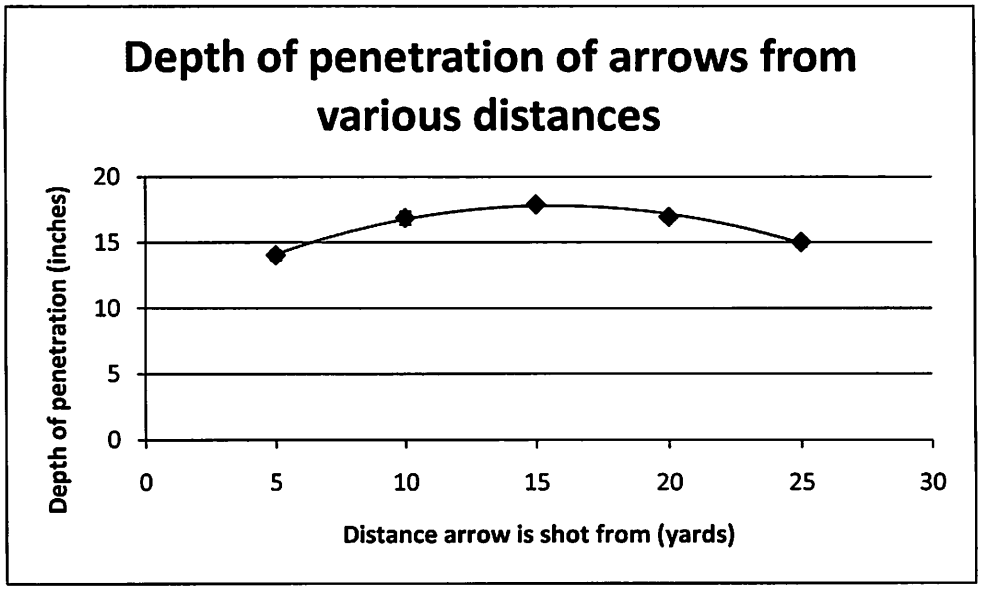
So the uncertainty of my data goes as follows:

Distance Arrow is Shot From (yards)	Average Depth of Penetration (inches)	Uncertainty (inches)
5	14.031	± 0.375
10	16.875	± 0.500
15	17.891	± 0.219
20	16.938	± 0.188
25	15.000	± 0.344

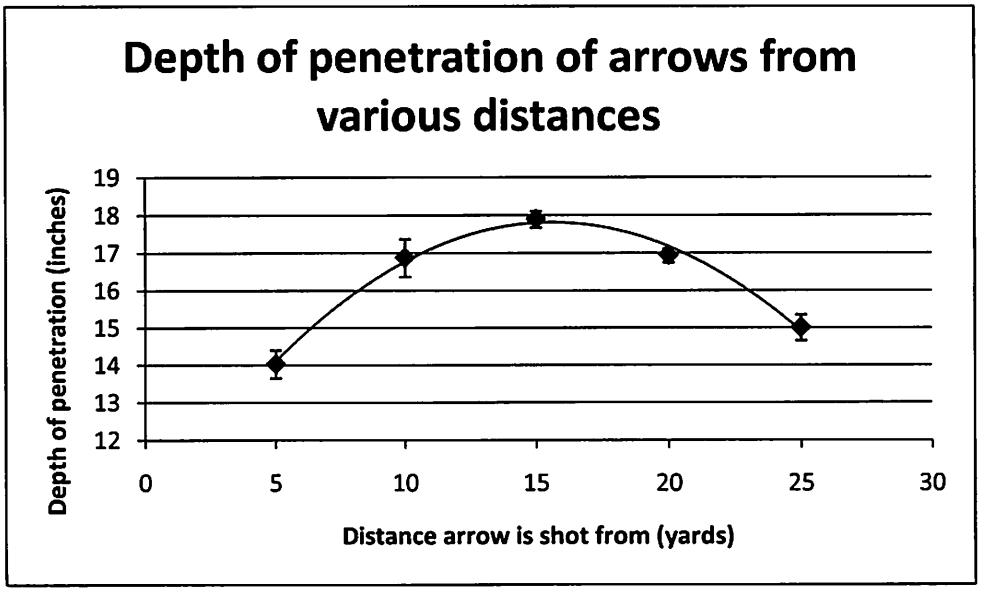
Data Collection and Processing 3

Below I have created a graph plotting my points and uncertainties and have also added a line of best fit with the equation: $y = (0.0329x^2 + 1.0284x + 9.7813$

Because I was certain of the distance I shot from I felt like the uncertainty bars for distance would be irrelevant so I did not include them.



Because my error bars may be difficult to see I included another graph with the same data only a more magnified view.



Conclusion

In my conclusion I am going to compare what I expected to get with what I actually got while conducting my experiment. I investigated the relationship between the distance the arrow was fired from in yards and the depth in inches at which it penetrated the target. From looking at the graph it can easily be seen that there is a relationship between the distance fired and the depth of penetration into the target. Although it is not a linear relationship as I had hypothesized but an inverse parabolic relationship. I

had first hypothesized that as the distance increased the depth of penetration of the arrow would have an inverse linear relationship meaning that the depth would decrease as the distance increases. But instead when I processed my graph I found that the depth would increase until a maximum value until it began to decrease creating an inverse parabolic relationship.

Scope and Limit

Upon reviewing my procedure I found some flaws within it. The first limitation I had noticed was that as I was conducting my experiment I was wearing down my target. As the arrow penetrated the target it would literally punch a hole in the target. Creating a particularly soft spot in the target. Although the odds of my arrow hitting the exact same spot as the previous arrow are very slim, if it were to hit the soft spot it would penetrate the target with a greater depth, adding an outlier to my data. Because I am marking the arrow shaft with a marker I may not have marked it in the correct spot because the arrow did not penetrate the target at exactly a 90° angle so I may have been slightly off on my marking causing my measurements to be slightly off. Another limitation to my experiment is the climate of my setting. A sudden gust of wind could have affected my arrow mid-flight and I would not have known. But the temperature of the setting was not a factor because the experiment was conducted was conducted in the same place, there was no variation in the temperature. Because the average depths all had a difference very close to one another we can assume that the measurements were all taken consistently.

Improvements

The experiment produced good results with uncertainties ranging from ± 0.188 to ± 0.500 inches, but this number could have been lowered. Because I was limited with the materials and setting I was conducting my experiment in. I would want to next time use more accurate measuring tools and multiple targets that are exactly the same in order to negate the chances of hitting a soft spot on the target. I would also prefer to conduct my experiment in an environment where I wouldn't have to worry about weather affecting my data in order to make the data I collect from my experiment more accurate.