NSTA
Nashville, April 2016

4 Analyzing and Interpreting Data

MONTANA STATE UNIVERSITY


Who ARe
you?

Conceptual Change...


Integration
(Building on 3 D Practice)
Reinterpreting Beliefs
(Reorganization of 3 D Beliefs)
Confronting Beliefs
(Questioning Pedagogy in light of 3 D)
Exposing Beliefs
(Questioning Validity of 3D Teaching)
Invention
(Onging 3 D Growth & Planting 3 D Seeds in Others)
Building Awareness
(Learning about the 3 Dimensions)

Practice 4 Analyzing and Interpreting Data

> *Once collected, data must be presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others. Because raw data as such have little meaning, a major practice of scientists is to organize and interpret data through tabulating, graphing, or statistical analysis. Such analysis can bring out the meaning of data—and their relevance—so that they may be used as evidence.*
>
> *Engineers, too, make decisions based on evidence that a given design will work; they rarely rely on trial and error. Engineers often analyze a design by creating a model or prototype and collecting extensive data on how it performs, including under extreme conditions. Analysis of this kind of data not only informs design decisions and enables the prediction or assessment of performance but also helps define or clarify problems, determine economic feasibility, evaluate alternatives, and investigate failures.* (NRC Framework, 2012, p. 61-62)

As students mature, they are expected to expand their capabilities to use a range of tools for tabulation, graphical representation, visualization, and statistical analysis. Students are also expected to improve their abilities to interpret data by identifying significant features and patterns, use mathematics to represent relationships between variables, and take into account sources of error. When possible and feasible, students should use digital tools to analyze and interpret data. Whether analyzing data for the purpose of science or engineering, it is important students present data as evidence to support their conclusions.

Grades K-2	Grades 3-5	Grades 6-8	Grades 9-12
Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations. • Record information (observations, thoughts, and ideas). • Use and share pictures, drawings, and/or writings of observations. • Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems. • Compare predictions (based on prior experiences) to what occurred (observable events). • Analyze data from tests of an object or tool to determine if it works as intended.	Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. • Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. • Analyze data to refine a problem statement or the design of a proposed object, tool, or process. • Use data to evaluate and refine design solutions.	Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. • Distinguish between causal and correlational relationships in data. • Analyze and interpret data to provide evidence for phenomena. • Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). • Analyze and interpret data to determine similarities and differences in findings. • Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. • Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Practice 4

Analyzing and Interpreting Data

Once collected, data must be presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others. Because raw data as such have little meaning, a major practice of scientists is to organize and interpret data through tabulating, graphing, or statistical analysis. Such analysis can bring out the meaning of data—and their relevance—so that they may be used as evidence.

skills

verbs

tools

products

High School

Complex analysis

Chi squared

Scatterplots

Statistical analysis

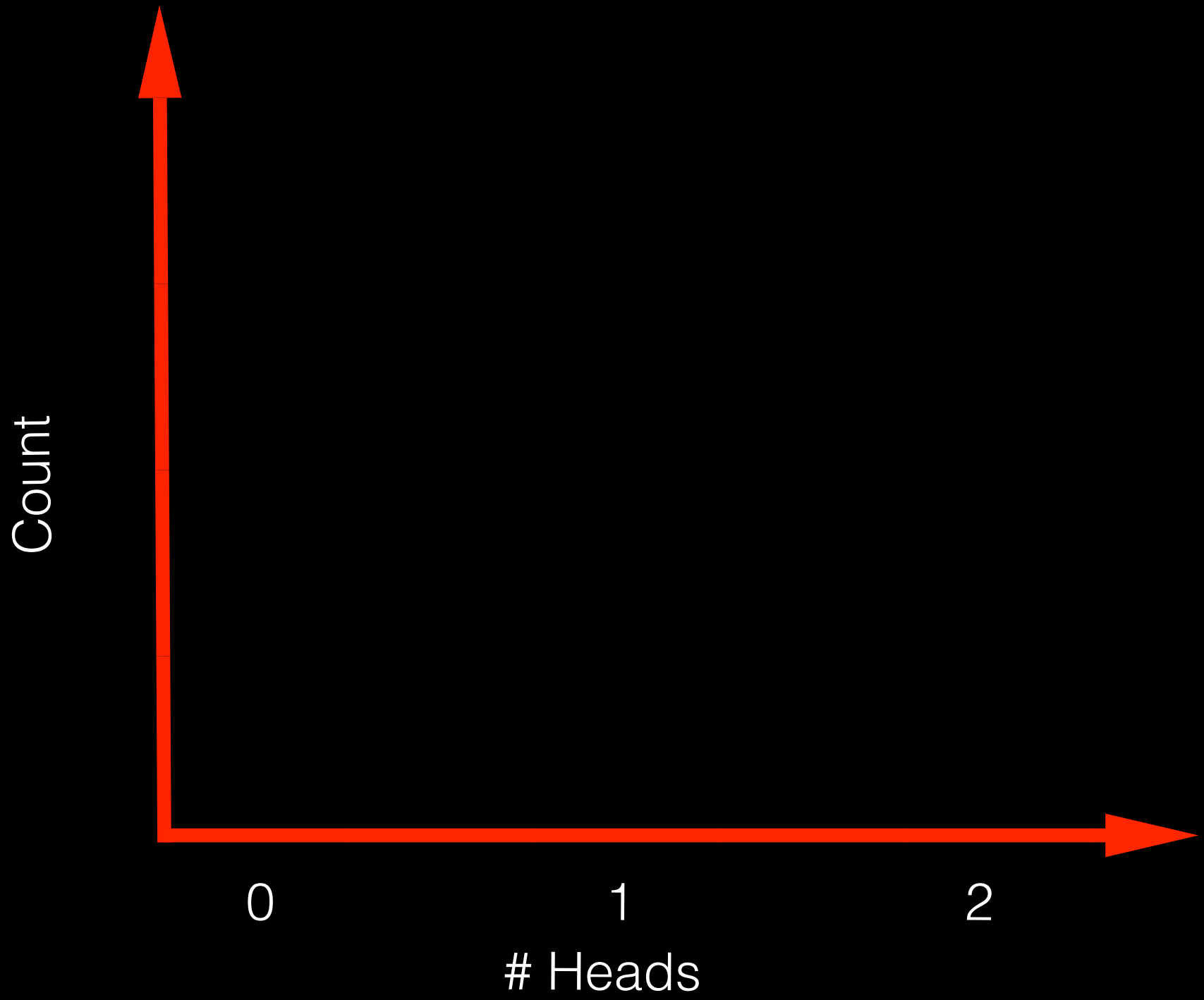
Computer simulations

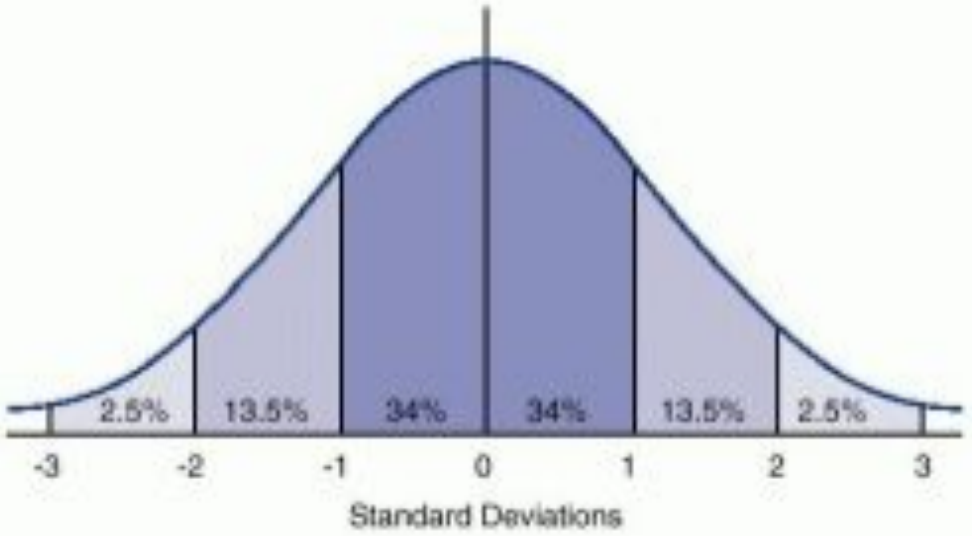
Large Data Sets

0 Heads

1 Head

2 Heads


Count
0
1
2
Heads



Normal distribution. The approximate percentage of the area (or frequency) lying under the curve between standard deviations is indicated.

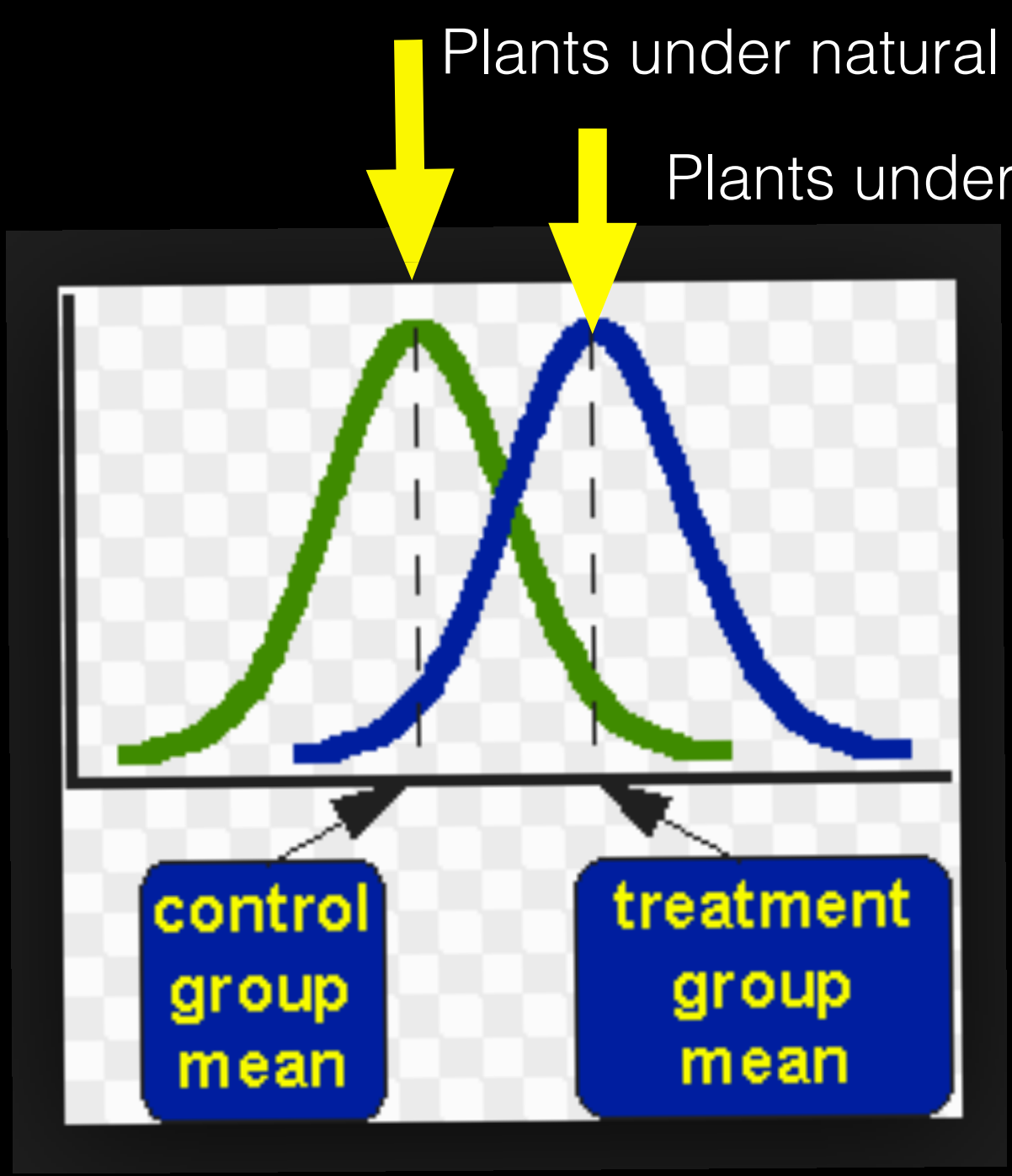
Natural Light (cm)	Artificial Light (cm)
46	45
46	45
46	46
47	47
47	48
47	49
48	51
49	52
49	54
50	51
50	55
50	54
51	58
51	57
52	58
52	48
52	57
52	61
53	61
53	60
54	55
54	58
54	54
55	55
55	64
55	63
56	62
56	63
56	58
57	62
57	60
57	58
59	57
59	55
59	58
59	55
59	52
60	55
52.94736842	55.28947368

Plants under natural light

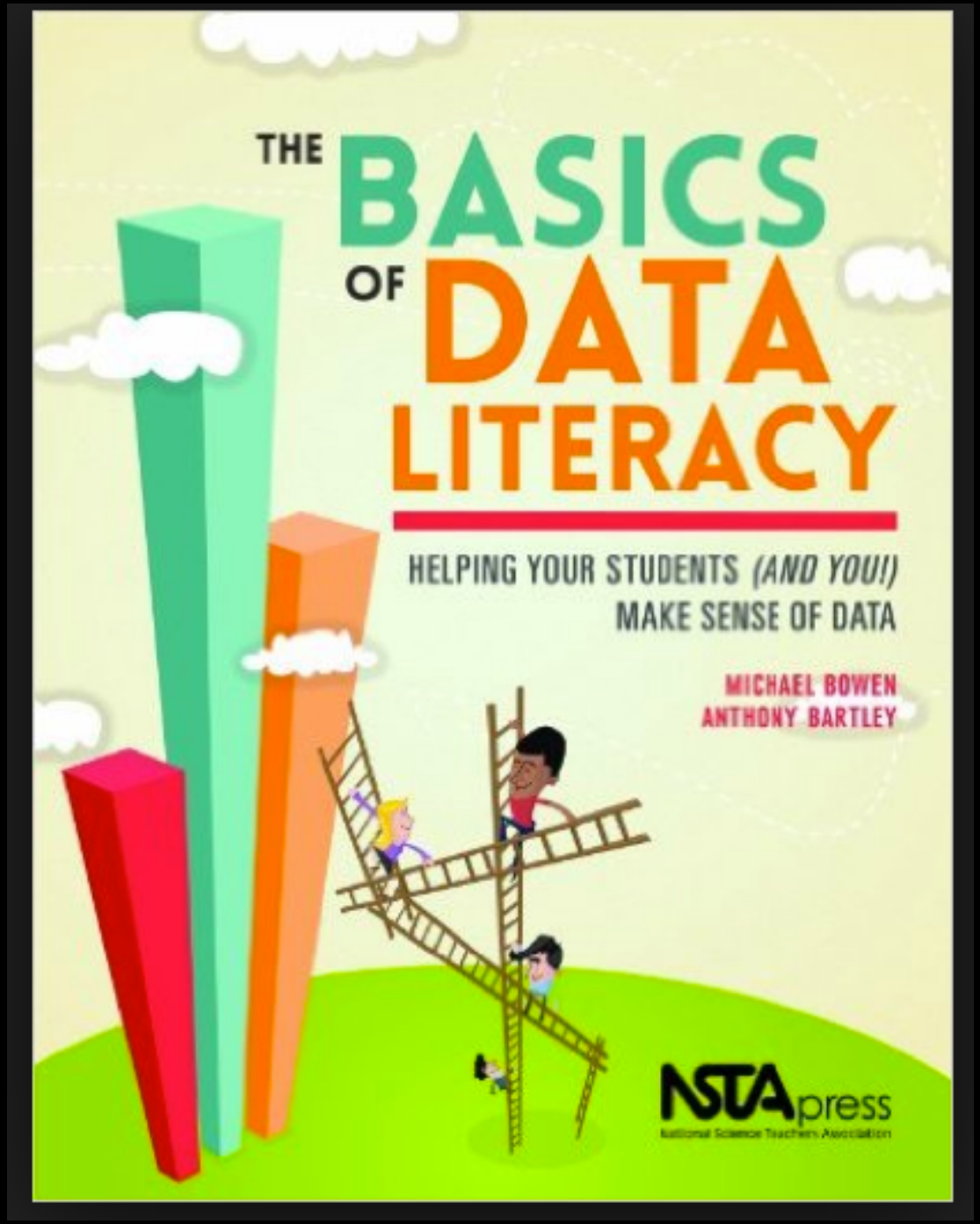
mean=52.9 cm

Plants under artificial light

mean=55.3 cm


Plants under natural light
Plants under artificial light
control group mean
treatment group mean

t-test


THE BASICS OF DATA LITERACY
HELPING YOUR STUDENTS (AND YOU!) MAKE SENSE OF DATA
MICHAEL BOWEN
ANTHONY BARTLEY
NSTApress
National Science Teachers Association

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Student T-Test Calculator for 2 Independent Means

The Calculator

Enter your sample values into the text boxes below, either one value per line or as a comma delimited list.

Population/Group 1

```
46
46
46
47
47
47
48
49
49
50
50
50
51
51
52
52
52
52
52
53
53
```

Population/Group 2

```
45
45
46
47
48
49
51
52
54
51
55
54
58
57
58
48
57
61
61
60
```

Significance Level:

- ○ 0.01
- ◉ 0.05
- ○ 0.10

95% confidence

One-tailed or two-tailed hypothesis?:

- ○ One-tailed
- ◉ Two-tailed

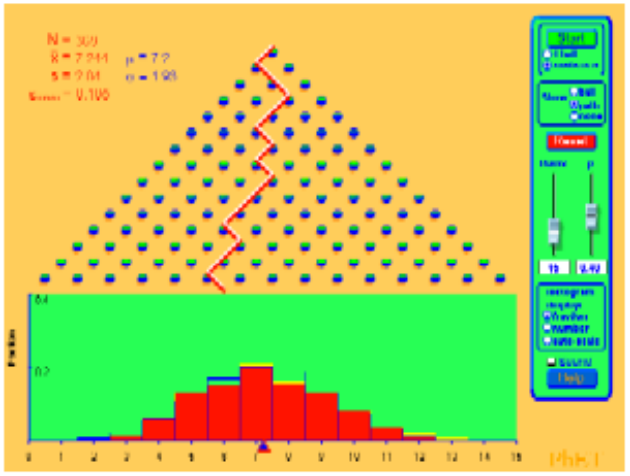
The T-value is 2.133927. The P-Value is 0.036163. The result is significant at p < 0.05.

Calculate T and P Values | Reset

Computer simulations

Large Data Sets

Plinko Probability



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NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Formerly the National Climatic Data Center (NCDC)... more about NCEI »

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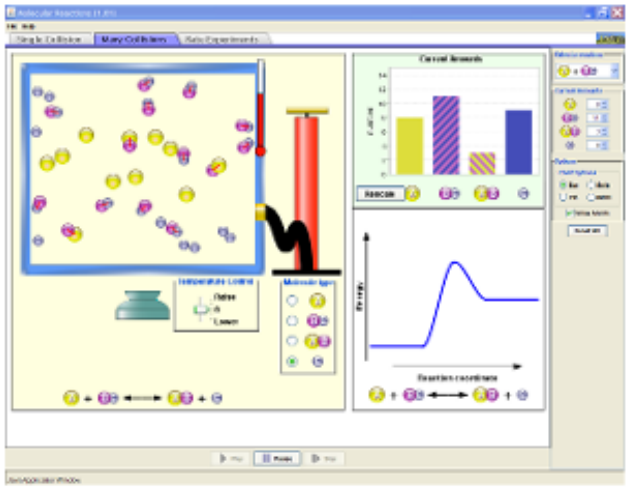
Home > Data Access > Quick Links

Reactions & Rates



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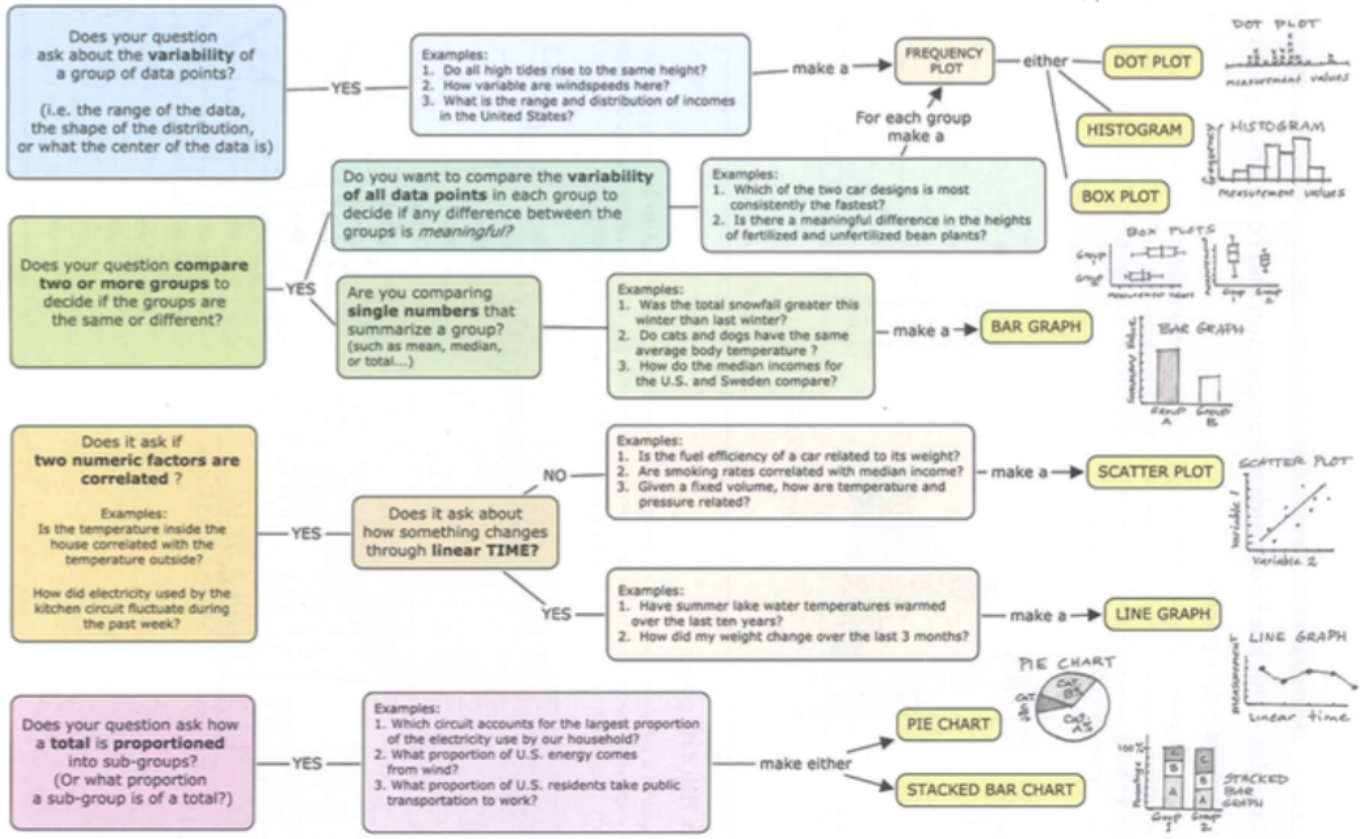
Science Teacher
Summer 2015

FIGURE 2

The Graph Choice Chart.

What question would you like to explore? Write your question as a complete sentence.

The Graph Choice. The Science Teacher. Nov. 2014, p. 40.



Crosscutting Concepts

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.					
Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.					
Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.					
Determine function fits to data, including slope, intercept, and correlation coefficient for linear fits.					
Compare and contrast various types of data sets (e.g., self-generated,					

Adapted from Brunsell E, Kneser D, Niemi K (2014), Introducing Teachers and Administrators to the NGSS. NSTA Press: Arlington, VA

Middle School

Display, Analyze, Interpret

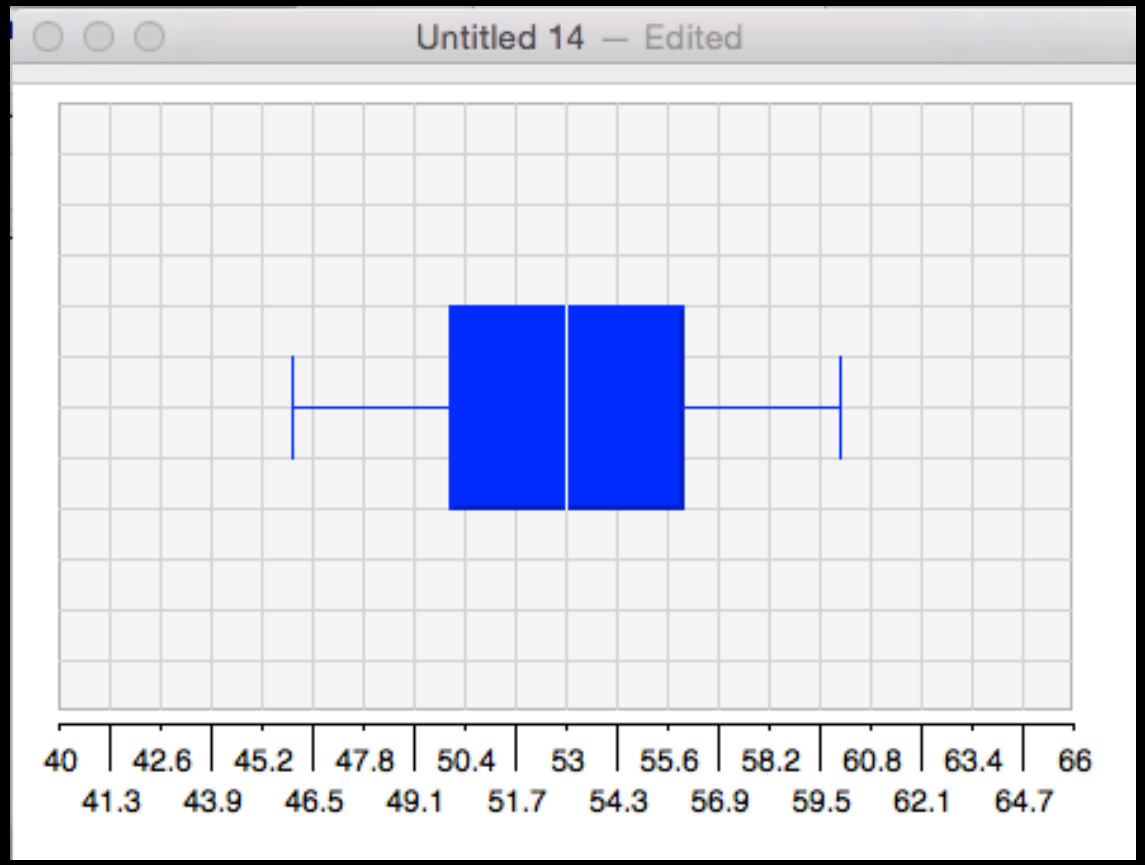
Graphing

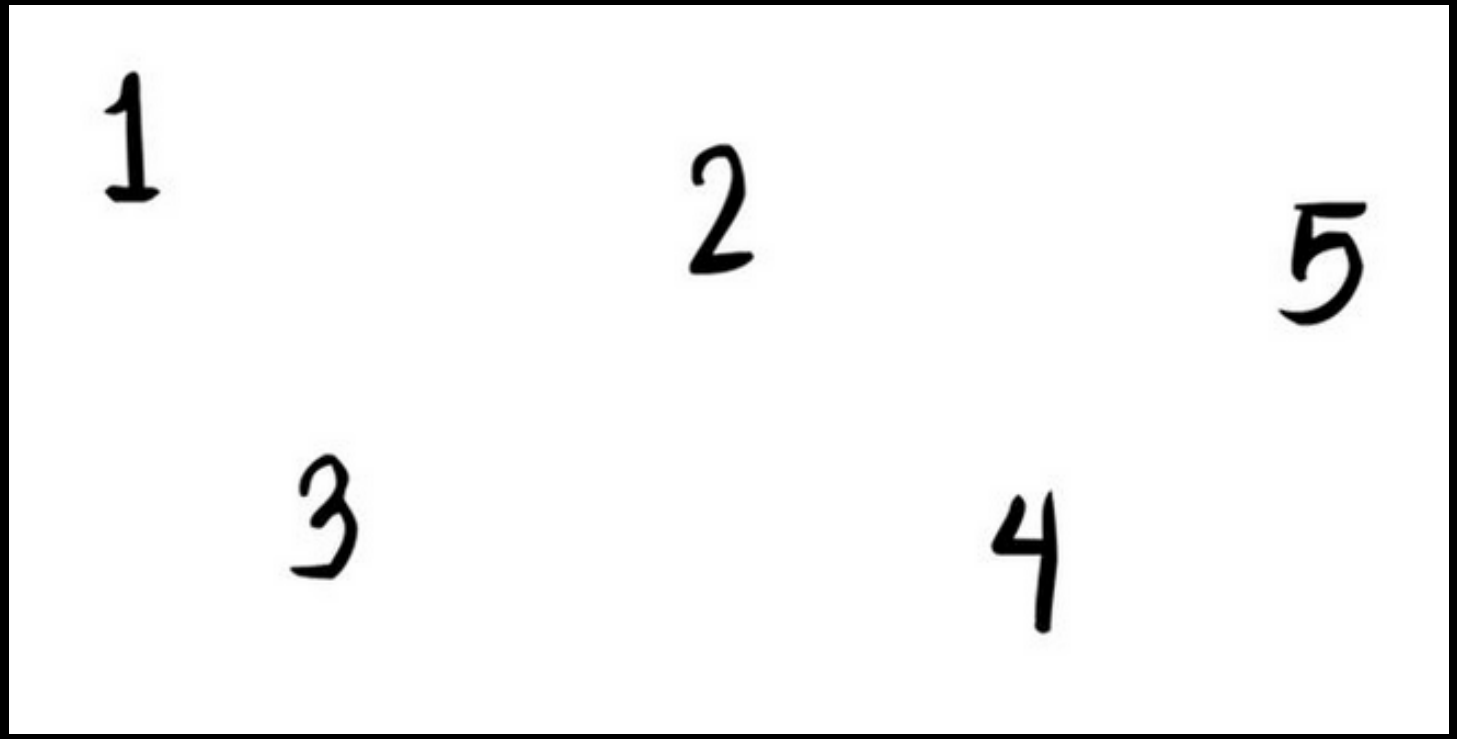
Outliers

Averaging

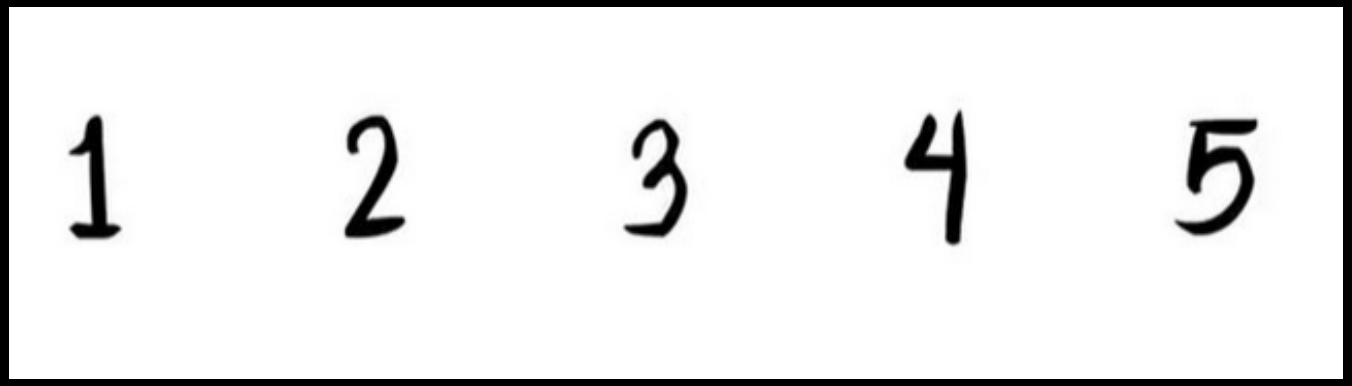
Measurement Error

Box and Whisker Plots

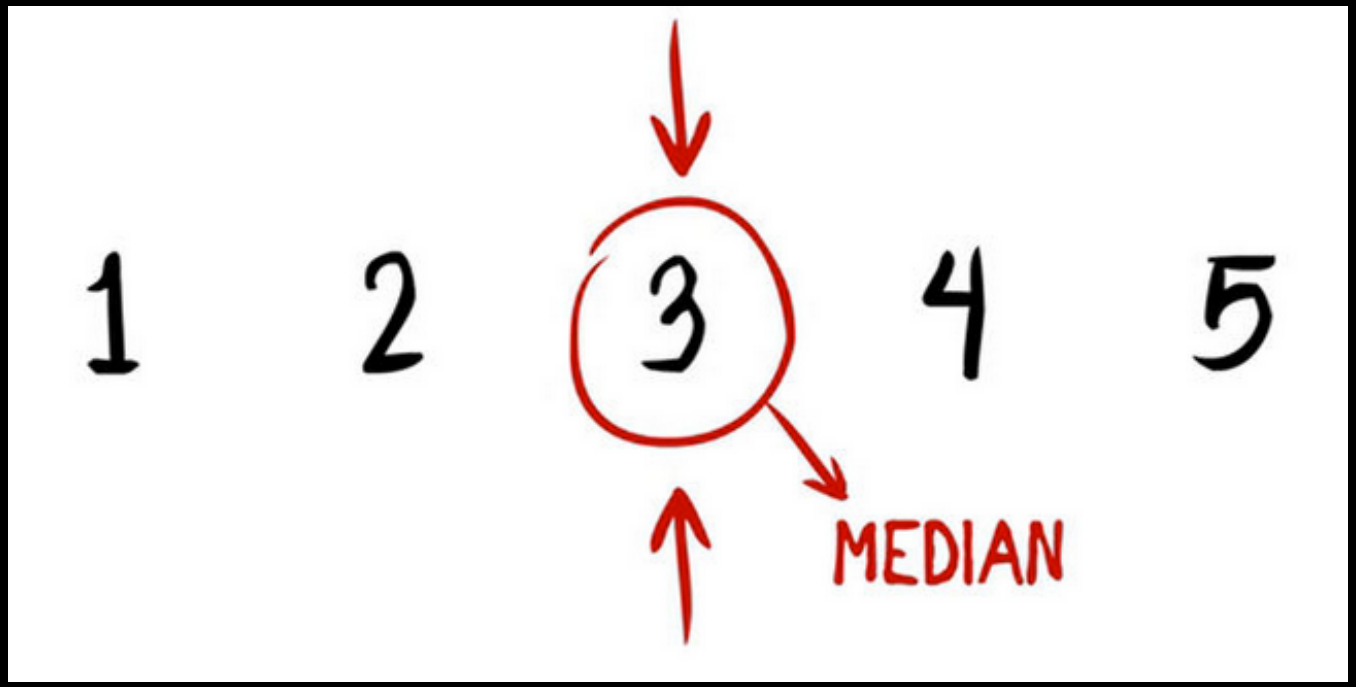




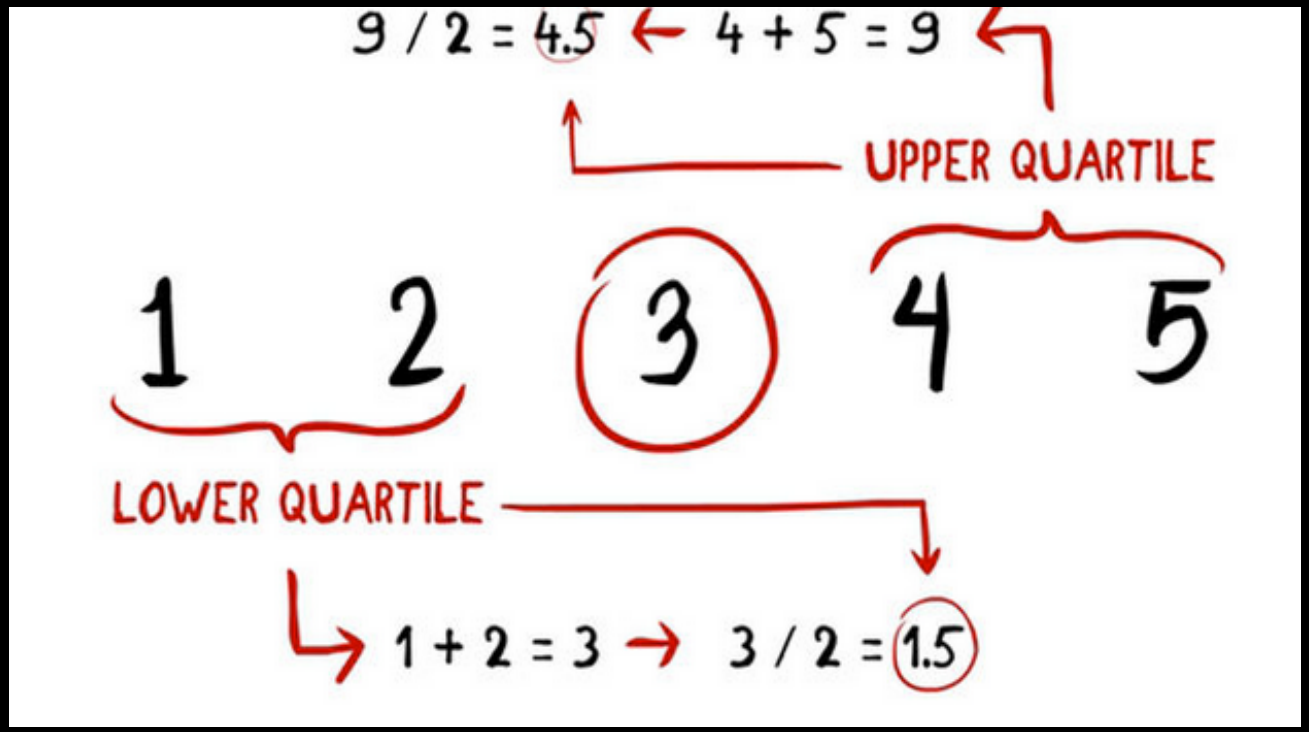
$$L \longrightarrow G$$



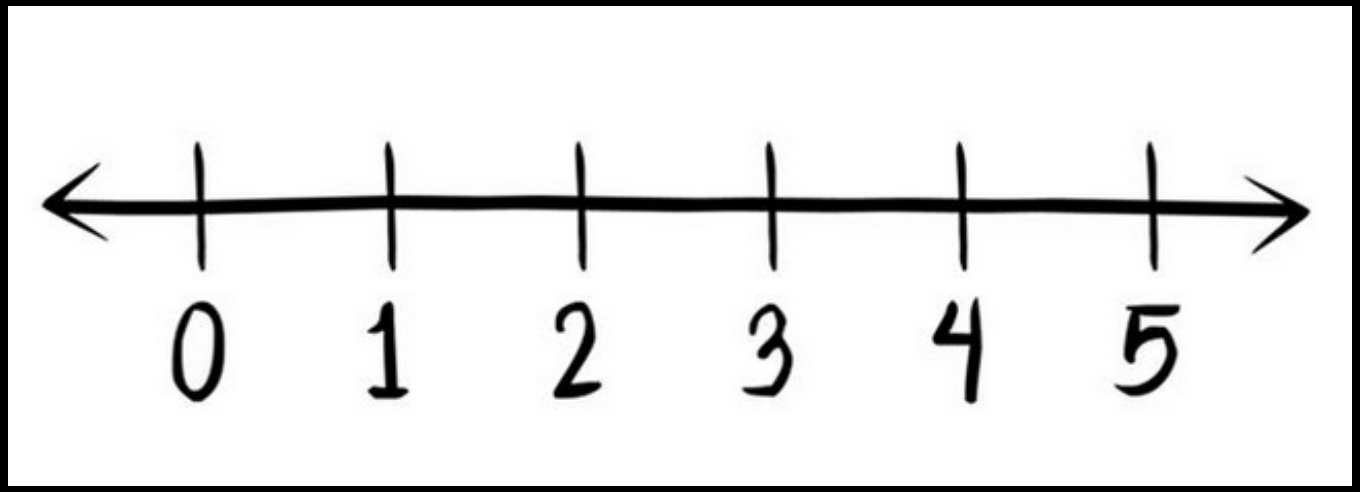
Circle Middle Number



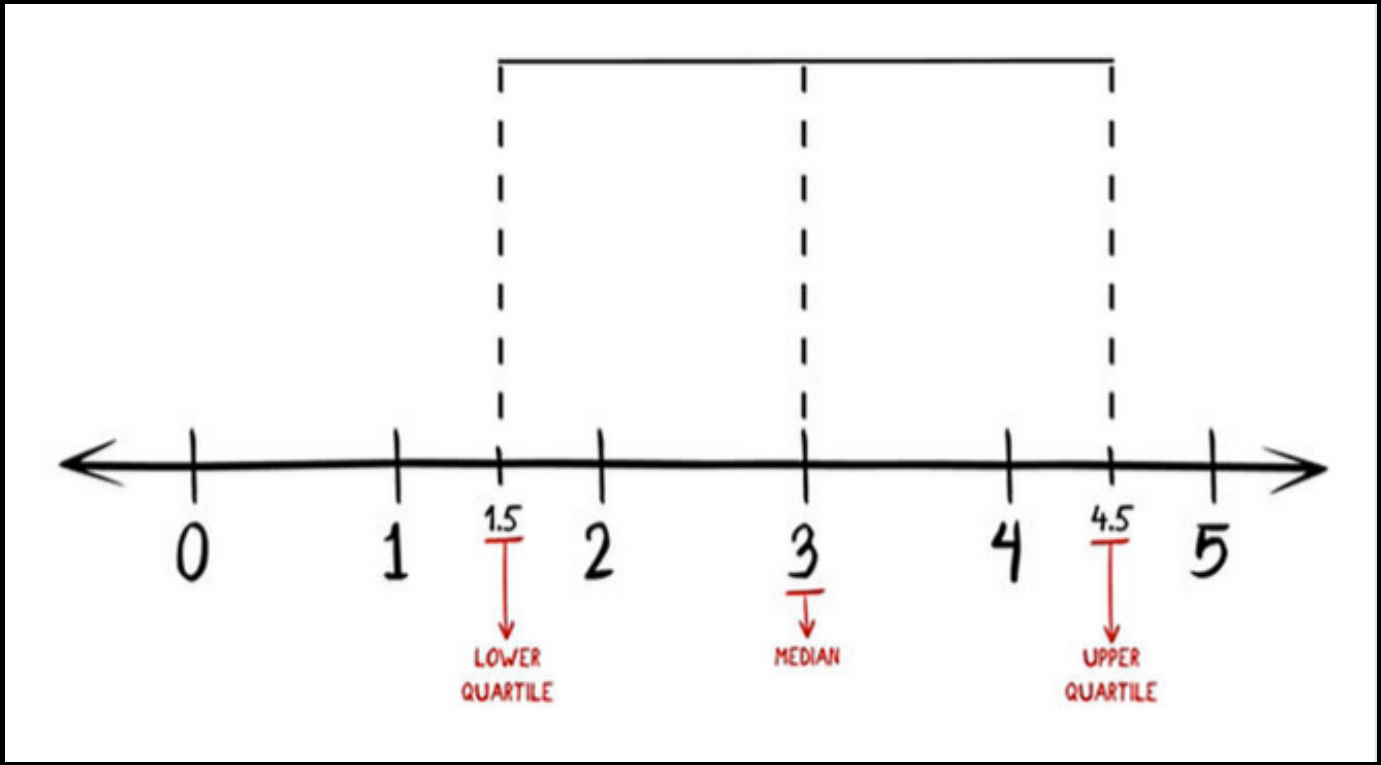
Find 1st/3rd Quartile



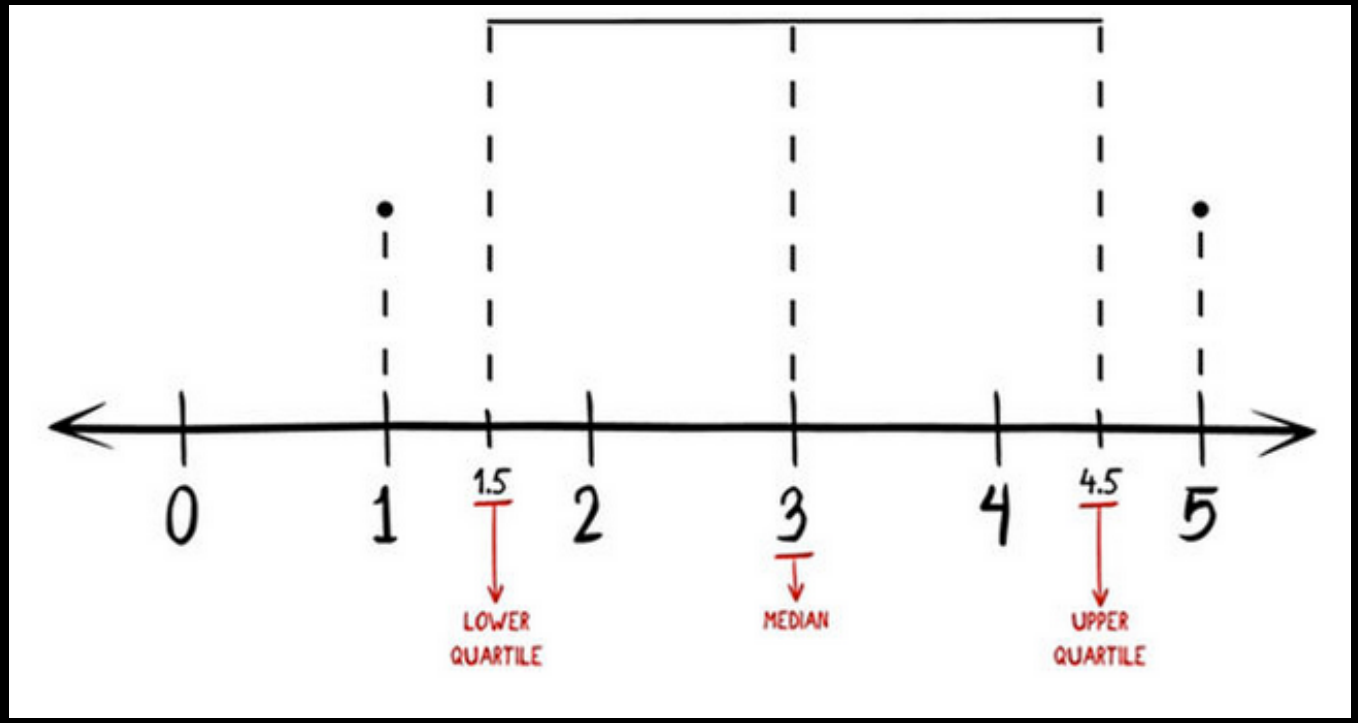
Draw a Plot Line



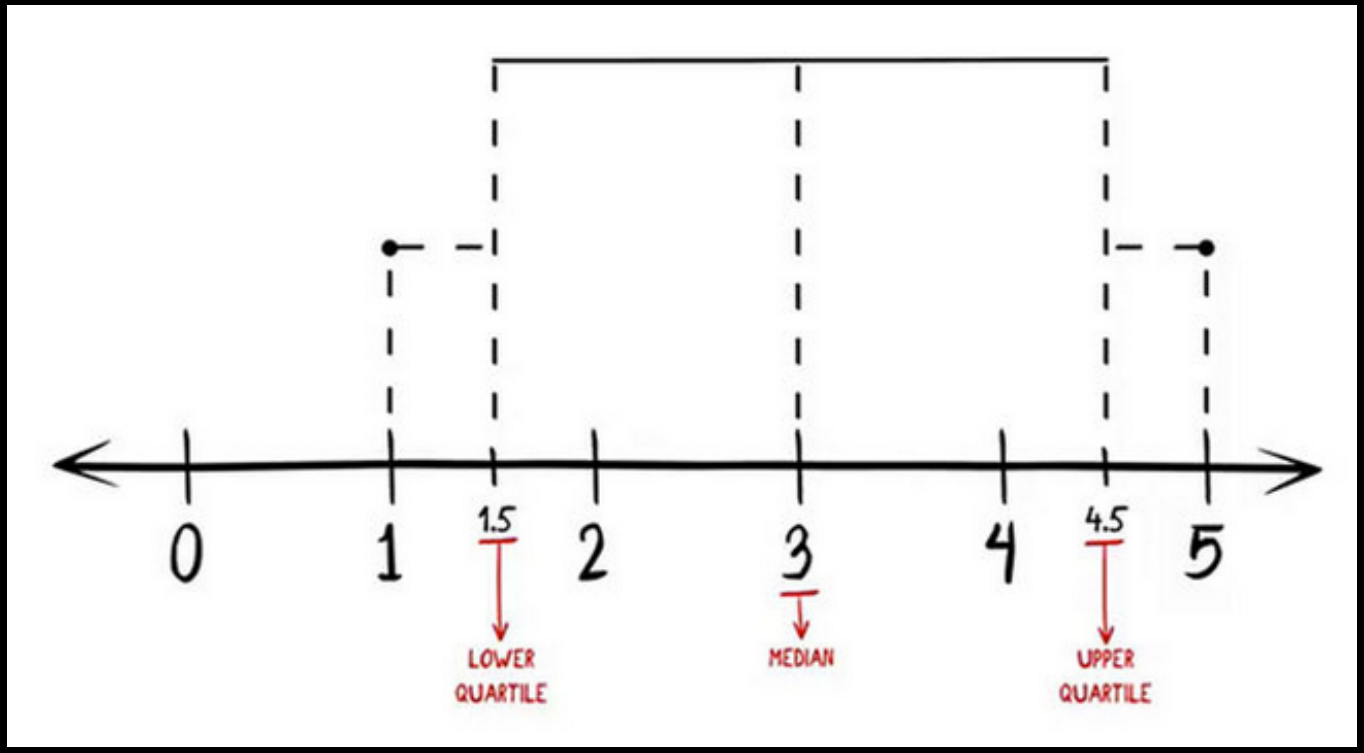
Mark 1st, 2nd, 3rd Quartiles on Line

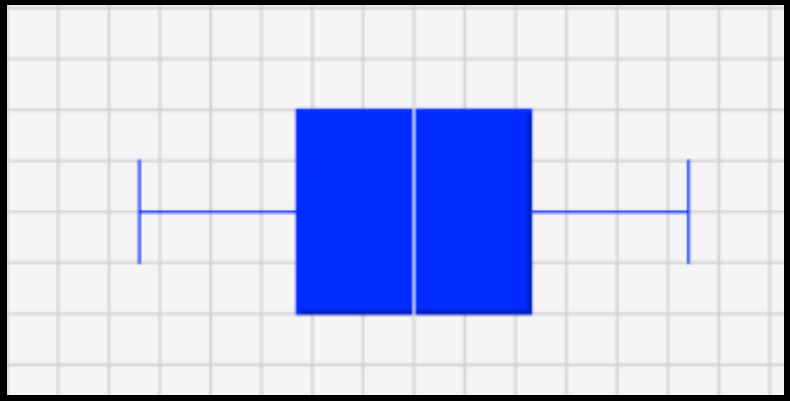


Mark Outliers

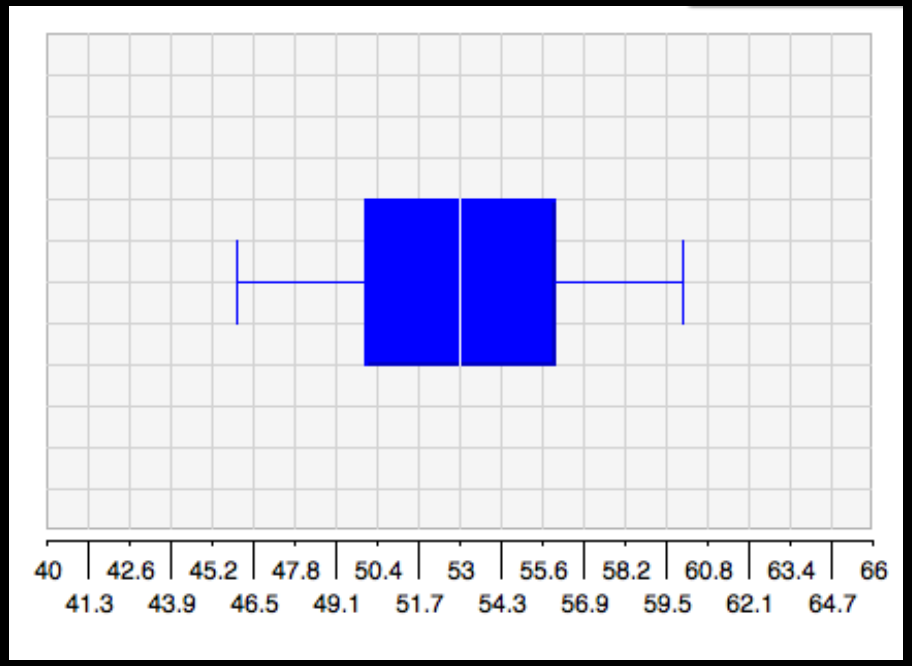


Connect Outliers w/ Horizontal Line

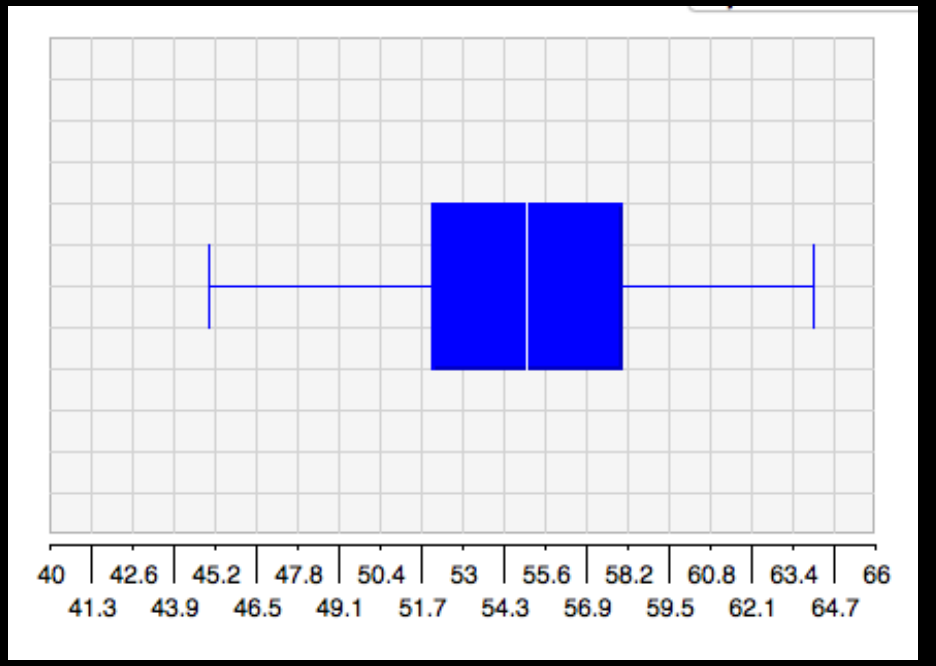

0
1
1.5
2
3
4
4.5
5
LOWER QUARTILE
MEDIAN
UPPER QUARTILE



Natural Light



Artificial Light

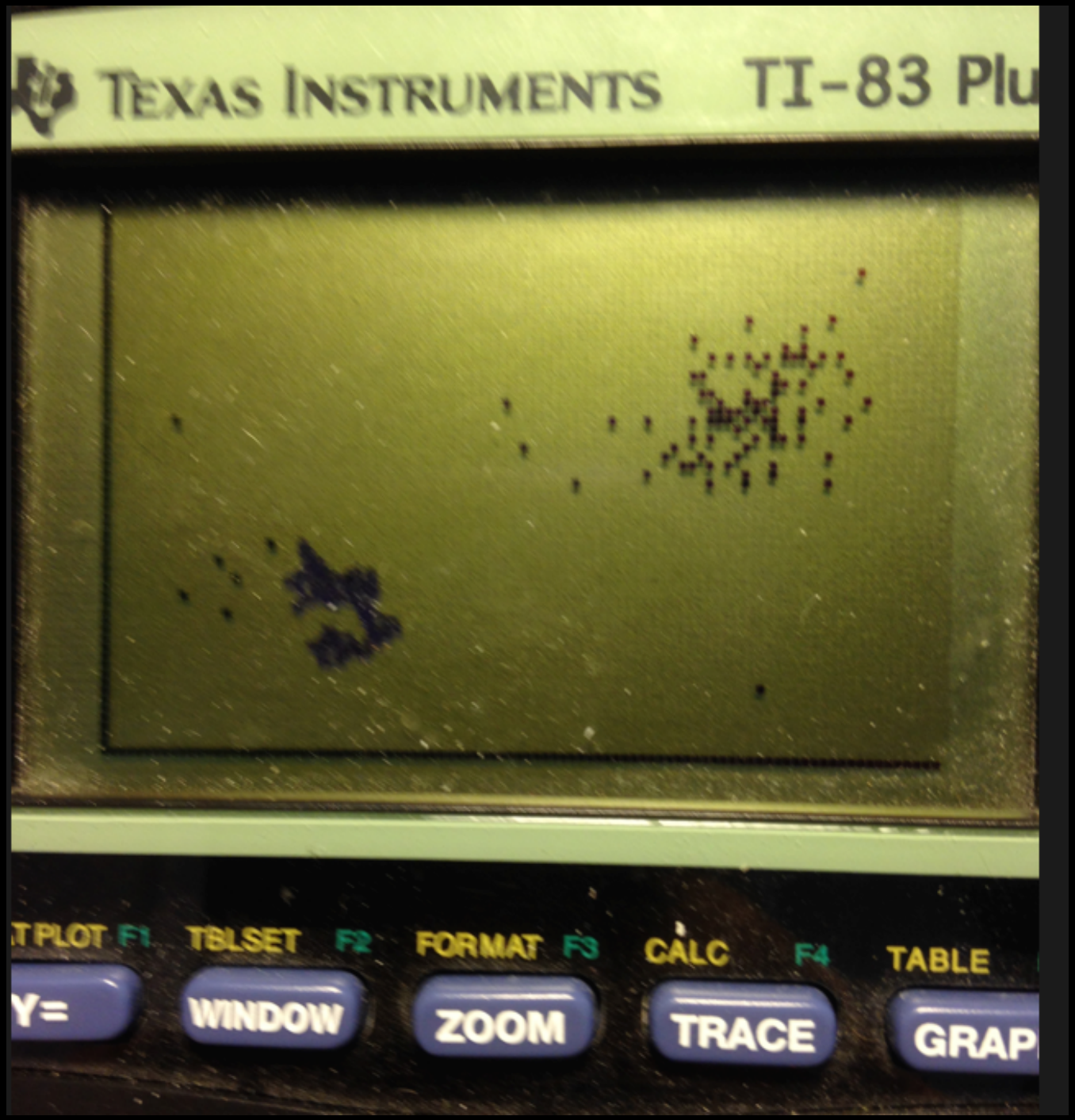


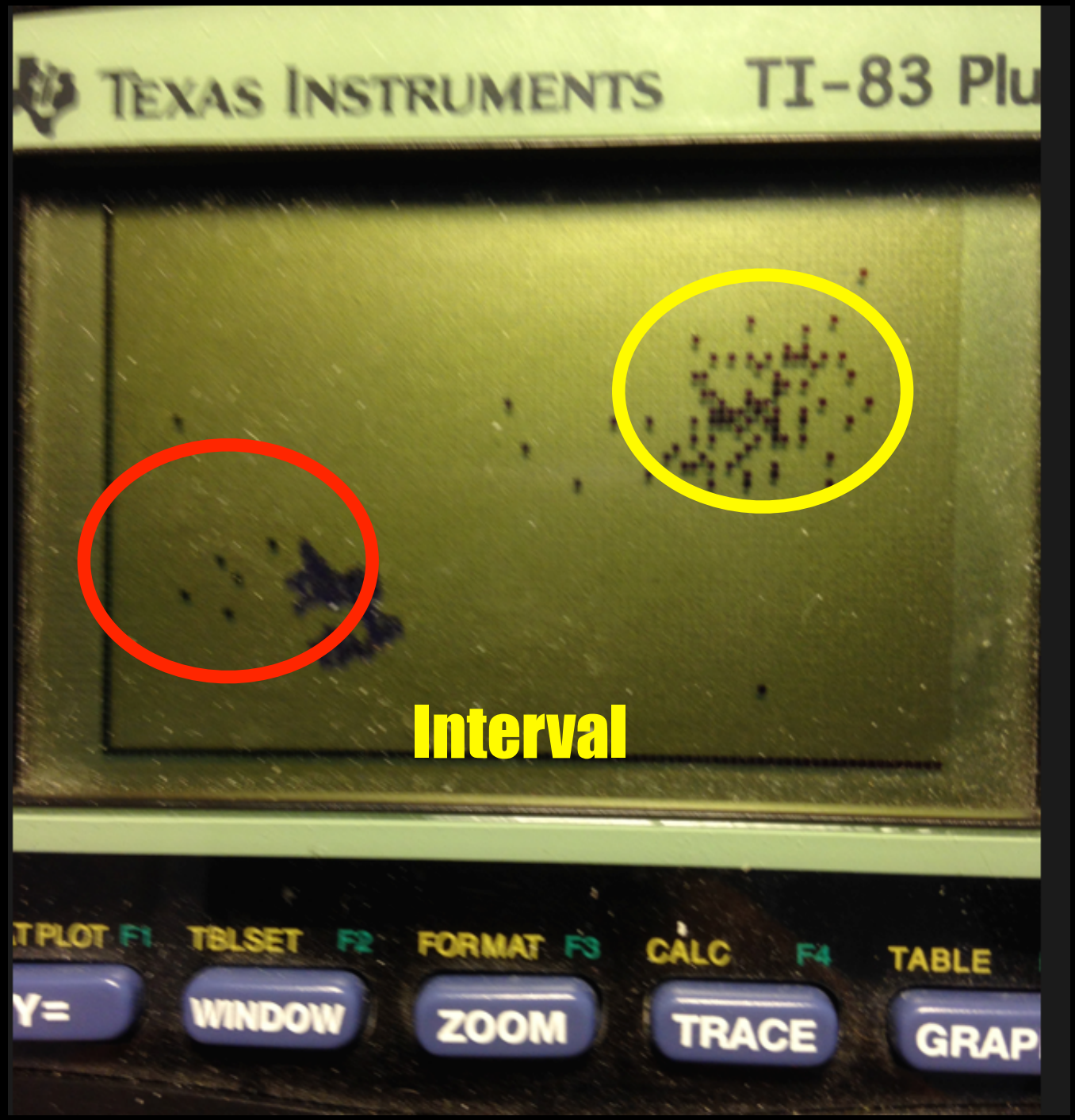
http://www.shodor.org/interactivate/activities/BoxPlot/

2127

OLD FAITHFUL ERUPTION DATA

	Time of Day	Duration (sec)	Interval (min)
9/1/99	9:03	253	83
9/1/99	10:31	247	88
9/1/99	11:57	255	86
9/1/99	13:25	276	88
9/1/99	14:55	256	90
9/1/99	16:29	251	94
9/1/99	17:59	1260	90
9/1/99	19:27	242	88
9/3/99	9:02	250	83
9/3/99	10:22	244	80
9/3/99	11:55	239	93
9/3/99	13:22	240	87
9/3/99	14:52	253	90
9/3/99	16:17	238	85
9/3/99	17:51	248	94
9/3/99	19:19	264	88
9/7/99	9:22	262	92
9/7/99	10:50	250	88
9/7/99	12:22	249	92
9/7/99	13:50	252	88
9/7/99	15:15	245	87
9/7/99	16:42	252	51
9/7/99	17:33	107	86
9/7/99	18:59	271	86
9/9/99	11:05	274	104
9/9/99	12:25	254	80
9/9/99	13:52	254	87
9/9/99	15:10	239	78
9/9/99	16:39	247	89
9/9/99	17:58	224	79
9/9/99	19:25	249	87
9/11/99	14:12	248	82
9/11/99	15:32	233	80
9/11/99	17:09	260	97
9/11/99	18:42	243	93
9/12/99	10:57	235	96
9/12/99	12:15	267	78
9/12/99	14:59	243	85
9/12/99	16:30	235	91
9/12/99	17:47	207	77
9/12/99	19:25	248	98
9/13/99	11:00	230	82
9/13/99	12:23	257	83
9/13/99	13:45	194	82
9/13/99	15:13	189	88
9/13/99	16:34	236	81
9/13/99	17:37	110	63
9/13/99	19:11	259	94
9/14/99	9:23	236	91
9/14/99	10:48	241	85
9/14/99	12:07	255	79
9/14/99	13:28	237	81
9/14/99	14:54	215	86
9/14/99	16:13	247	79
9/14/99	17:42	237	89
9/14/99	19:05	240	83
9/15/99	10:41	240	89
9/15/99	12:05	245	84
9/15/99	13:26	228	81
9/15/99	14:46	235	80
9/15/99	16:13	261	87
9/15/99	17:18	122	65
9/16/99	10:28	256	90
9/16/99	11:55	242	87
9/16/99	13:21	224	86
9/16/99	14:43	247	82
9/16/99	16:17	257	94
9/16/99	17:37	238	80
9/16/99	19:00	235	82
9/19/99	10:15	255	89
9/19/99	11:40	261	85
9/19/99	12:40	120	60
9/19/99	14:13	261	93
9/19/99	17:01	247	77
9/19/99	18:08	119	67
9/21/99	10:19	150	65
9/21/99	11:54	261	95
9/21/99	13:21	244	87
9/21/99	14:47	235	86
9/21/99	16:15	250	88
9/21/99	17:36	246	81
9/21/99	19:09	265	93
9/25/99	10:56	261	94
9/25/99	12:34	266	98
9/25/99	14:08	270	94
9/25/99	15:29	267	81
9/25/99	16:54	251	85
9/25/99	18:20	247	86
8/1/99	11:00	254	91
8/1/99	12:24	255	84
8/1/99	13:33	131	69
8/1/99	15:04	272	91
8/1/99	16:29	244	85
8/1/99	17:59	260	90
8/1/99	19:29	254	90
8/6/99	10:01	256	95
8/6/99	11:24	260	83

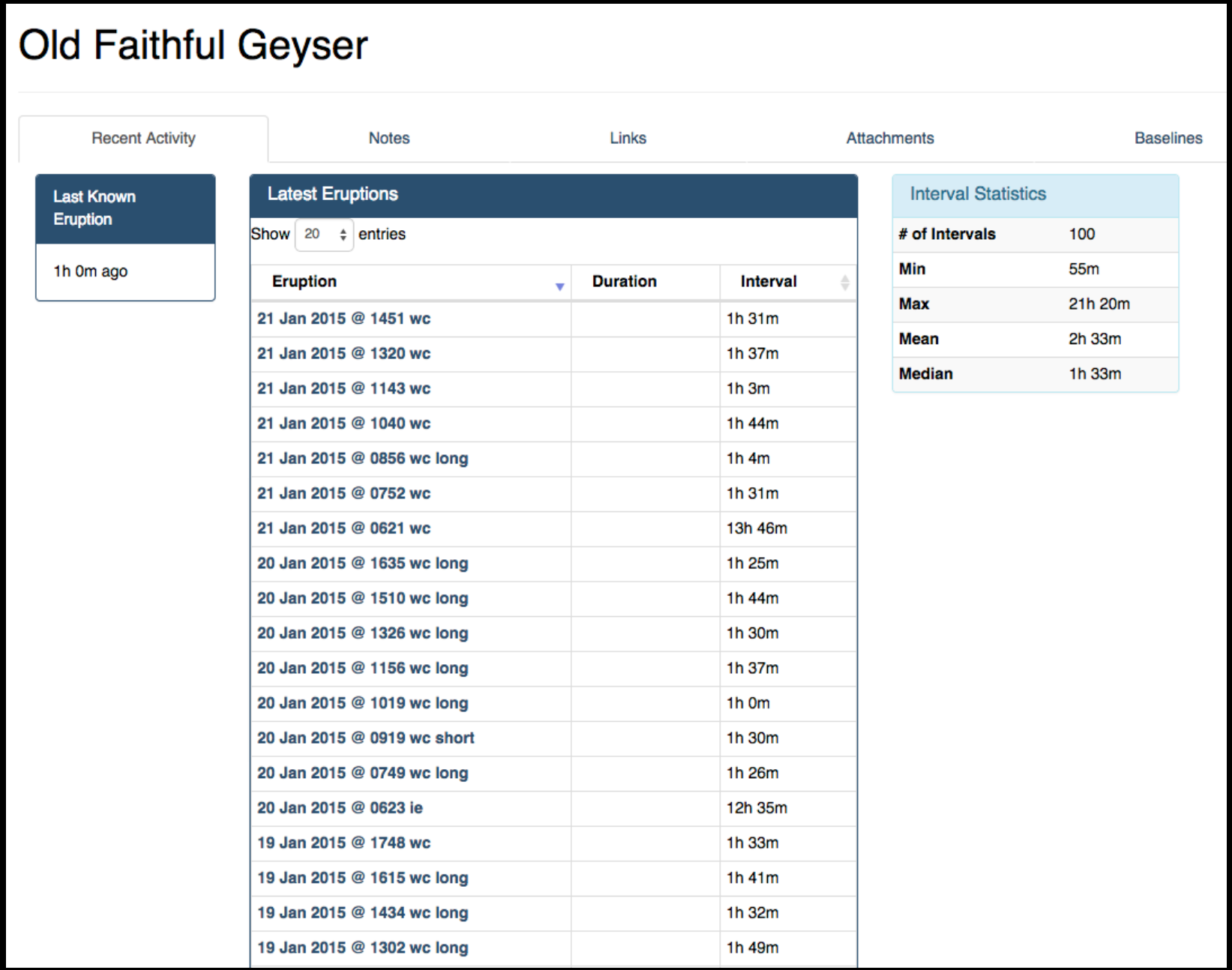

TEXAS INSTRUMENTS
TI-83 Plu
T PLOT F1
TBLSET F2
FORMAT F3
CALC F4
TABLE
Y=
WINDOW
ZOOM
TRACE
GRAP


TEXAS INSTRUMENTS TI-83 Plu
Duration
Interval
T PLOT F1 TBLSET F2 FORMAT F3 CALC F4 TABLE
Y=
WINDOW
ZOOM
TRACE
GRAP

63

88

http://www.geysertimes.org/



Old Faithful Geyser

Recent Activity | Notes | Links | Attachments | Baselines

Last Known Eruption

1h 0m ago

Latest Eruptions

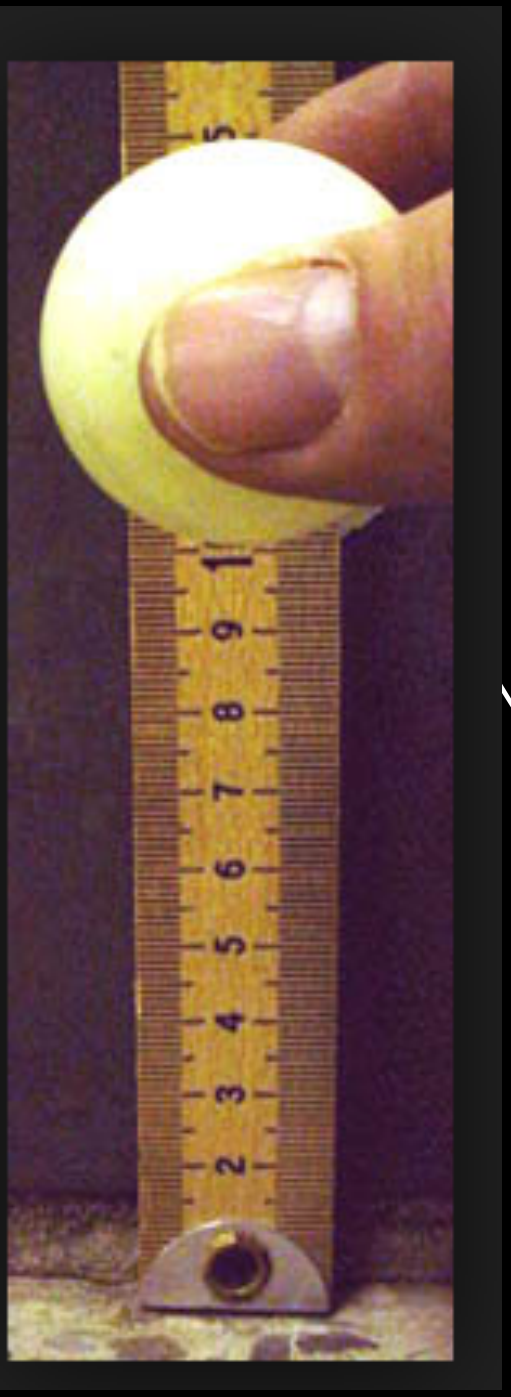
Show 20 entries

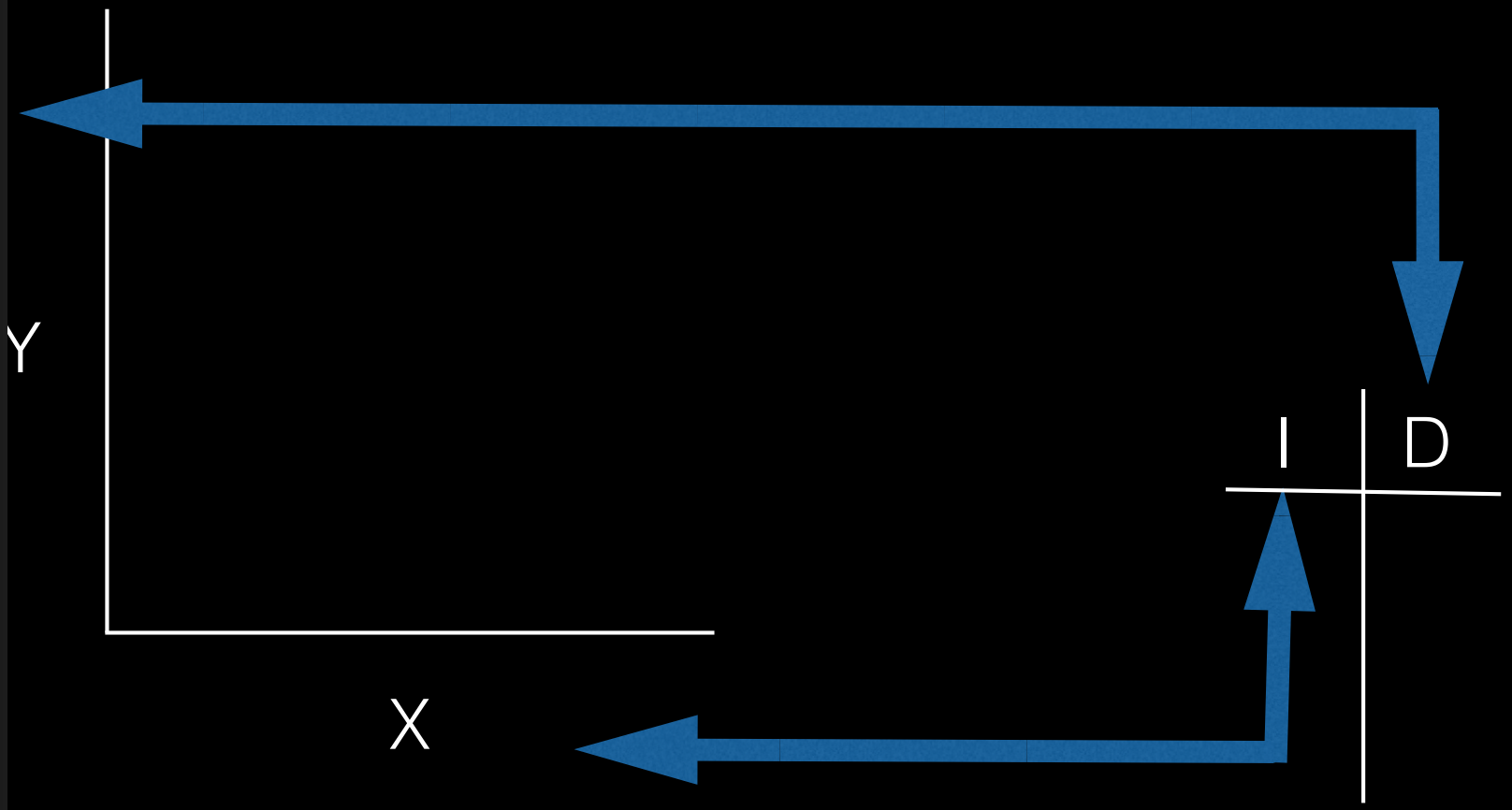
Eruption	Duration	Interval
21 Jan 2015 @ 1451 wc		1h 31m
21 Jan 2015 @ 1320 wc		1h 37m
21 Jan 2015 @ 1143 wc		1h 3m
21 Jan 2015 @ 1040 wc		1h 44m
21 Jan 2015 @ 0856 wc long		1h 4m
21 Jan 2015 @ 0752 wc		1h 31m
21 Jan 2015 @ 0621 wc		13h 46m
20 Jan 2015 @ 1635 wc long		1h 25m
20 Jan 2015 @ 1510 wc long		1h 44m
20 Jan 2015 @ 1326 wc long		1h 30m
20 Jan 2015 @ 1156 wc long		1h 37m
20 Jan 2015 @ 1019 wc long		1h 0m
20 Jan 2015 @ 0919 wc short		1h 30m
20 Jan 2015 @ 0749 wc long		1h 26m
20 Jan 2015 @ 0623 ie		12h 35m
19 Jan 2015 @ 1748 wc		1h 33m
19 Jan 2015 @ 1615 wc long		1h 41m
19 Jan 2015 @ 1434 wc long		1h 32m
19 Jan 2015 @ 1302 wc long		1h 49m

Interval Statistics

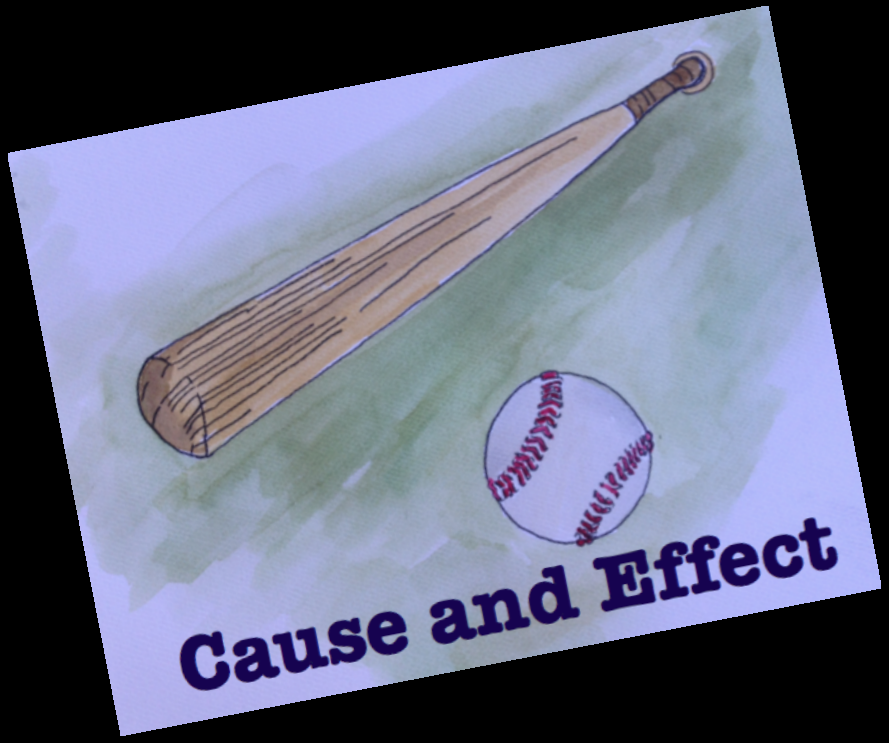
# of Intervals	100
Min	55m
Max	21h 20m
Mean	2h 33m
Median	1h 33m

From tables to graphs





Crosscutting Concepts



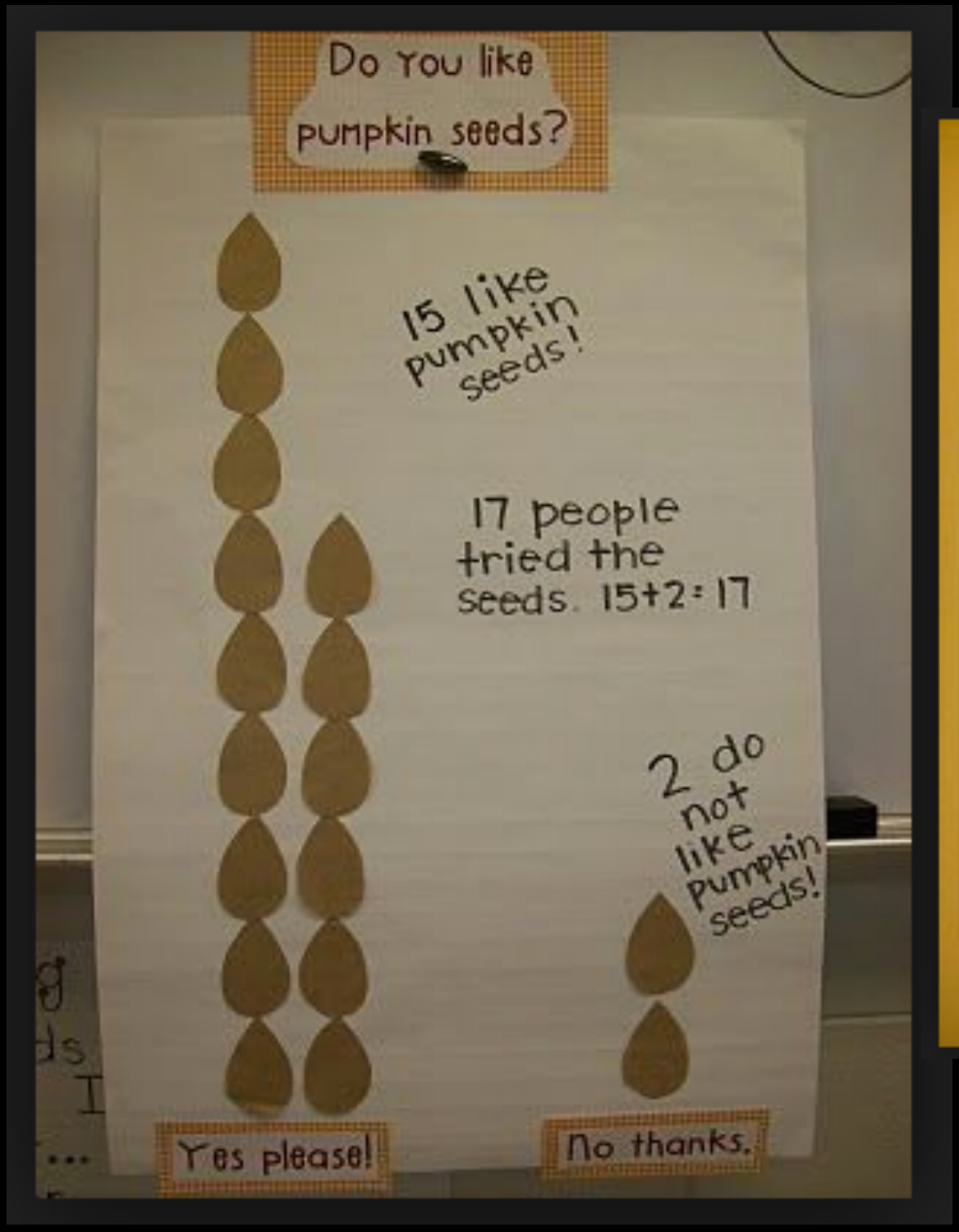
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.					
Use mean, median, mode, and variability to analyze and characterize data.					
Use graphical displays to analyze data in order to identify linear and nonlinear relationships.					
Consider limitations of data analysis, such as measurement error, and seek to improve precision and accuracy of data with better technological tools and methods such as multiple trials.					
Distinguish between causal and correlational relationships.					
Use data to define an operational range for a design solution.					

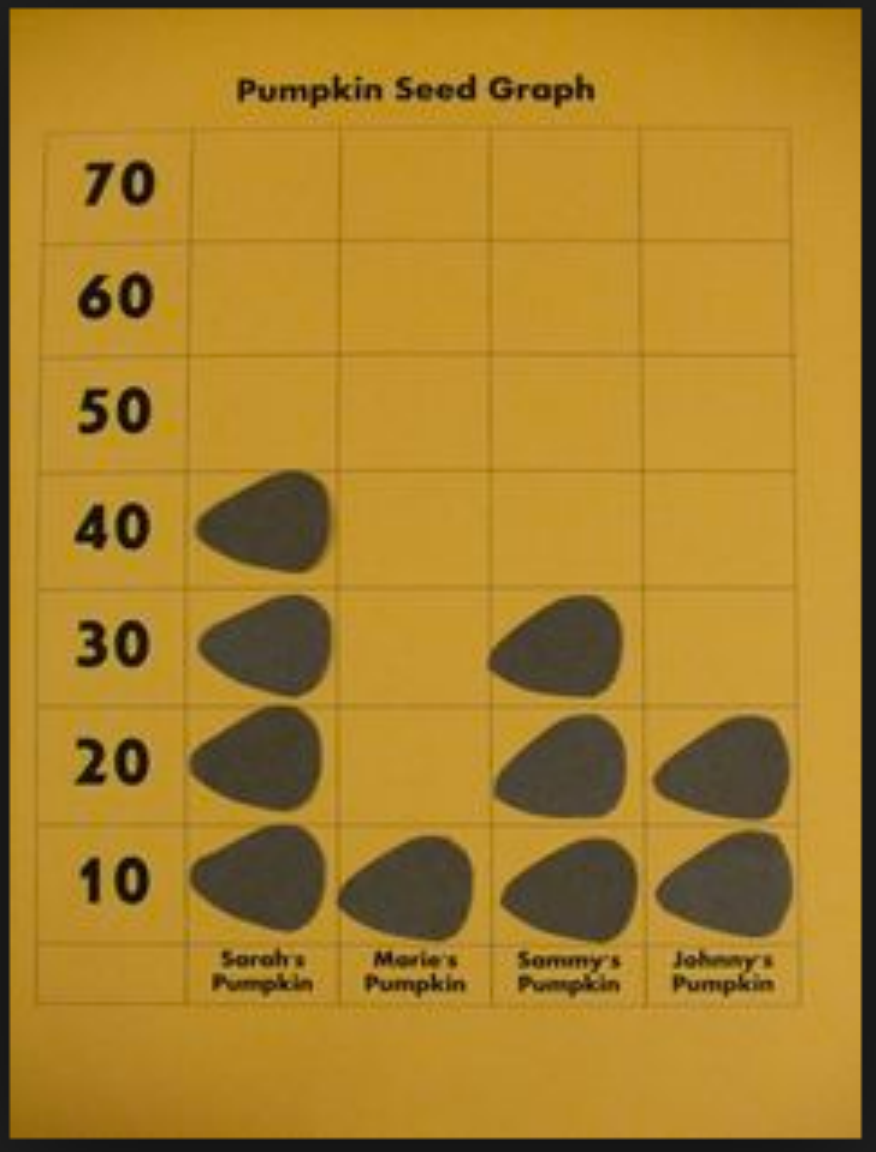
Adapted from Brunsell E, Kneser D, Niemi K (2014), Introducing Teachers and Administrators to the NGSS. NSTA Press: Arlington, VA

Elementary

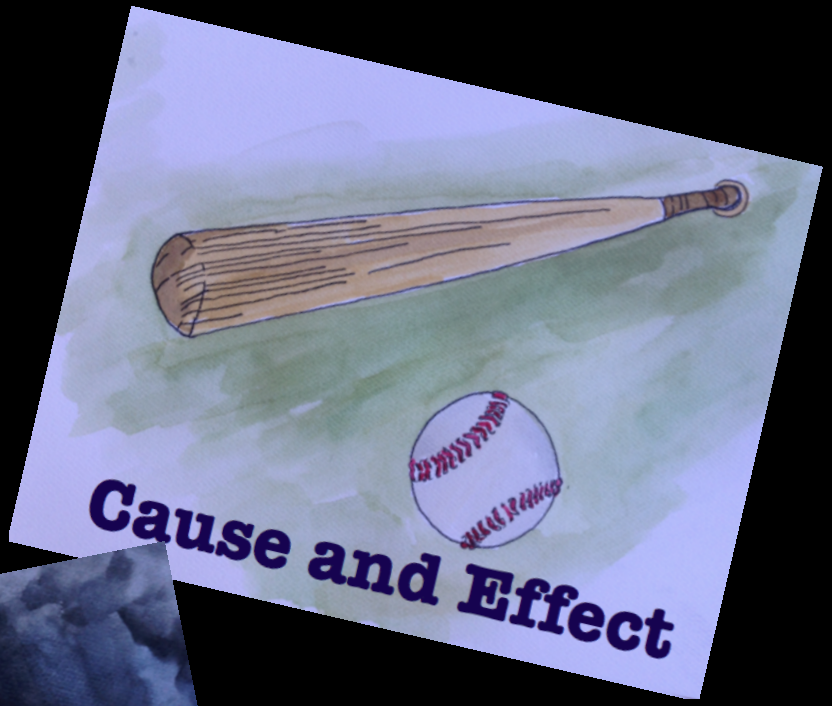
Graph
Record Observations
Collect Data
Make Tables
Engage in Inquiry

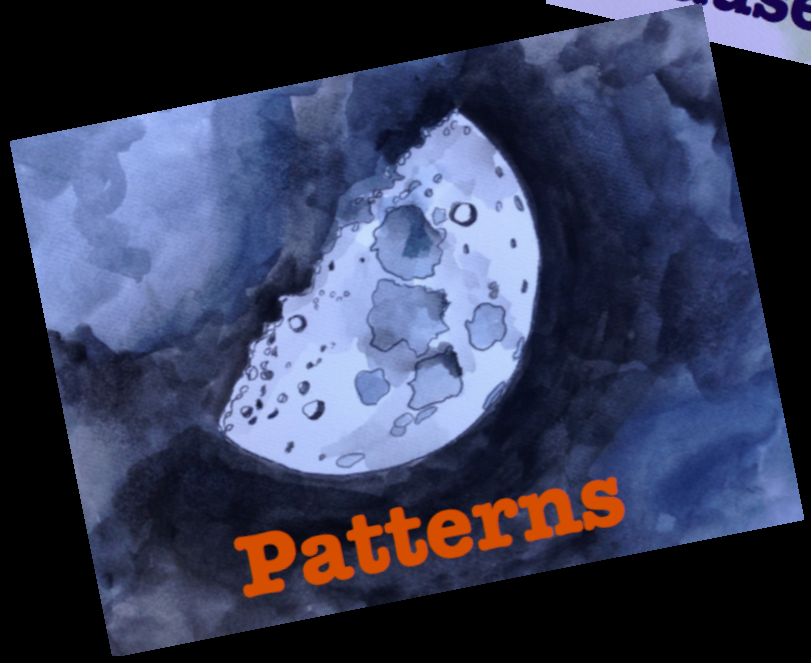
Elementary Activity


Do you like pumpkin seeds?
15 like pumpkin seeds!
17 people tried the seeds. 15+2=17
2 do not like pumpkin seeds!
Yes please!
No thanks.


Pumpkin Seed Graph
70
60
50
40
30
20
10
Sarah's Pumpkin
Marie's Pumpkin
Sammy's Pumpkin
Johnny's Pumpkin

Crosscutting Concepts

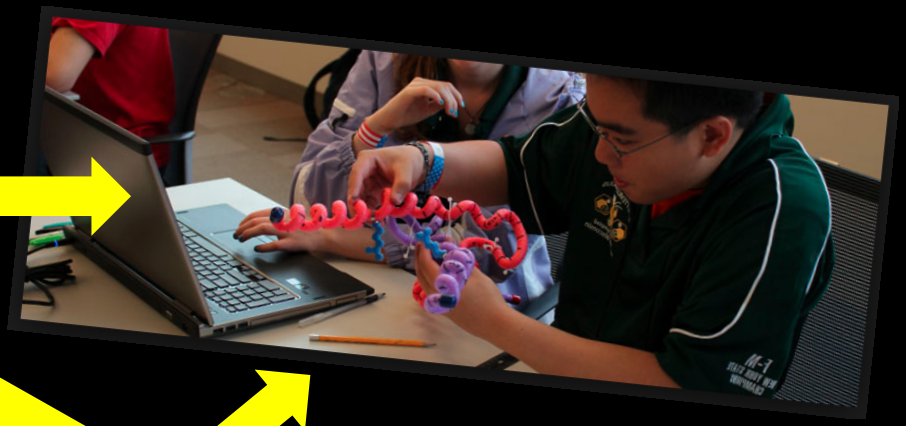




Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.					
Record information (observations, thoughts, and ideas).					
Use and share pictures, drawings, and/or writings of observations.					
Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.					
Compare predictions (based on prior experiences) to what occurred (observable events).					
Analyze data from tests of an object or tool to determine if it works as intended.					

Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.					
Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships.					
Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.					
Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.					
Analyze data to refine a problem statement or the design of a proposed object, tool, or process.					
Use data to evaluate and refine design solutions.					

Interconnectedness of Practices

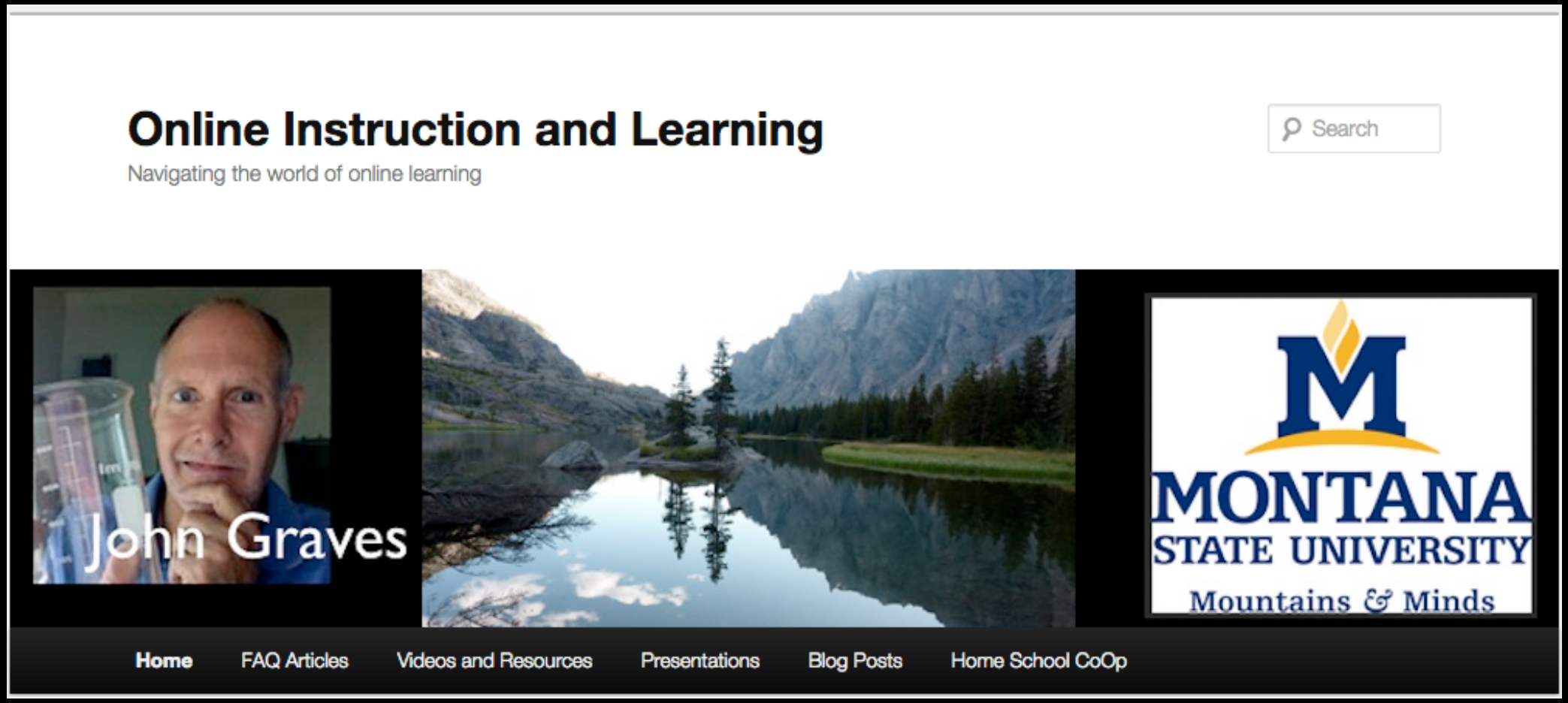


Engaging in Argumentation

Analyzing and Interpreting Data

Using Mathematics and Computational Thinking


Integration
(Building on 3 D Practice)
Reinterpreting Beliefs
(Reorganization of 3 D Beliefs)
Confronting Beliefs
(Questioning Pedagogy in light of 3 D)
Exposing Beliefs
(Questioning Validity of 3D Teaching)
Invention
(Onging 3 D Growth & Planting 3 D Seeds in Others)
Building Awareness
(Learning about the 3 Dimensions)



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