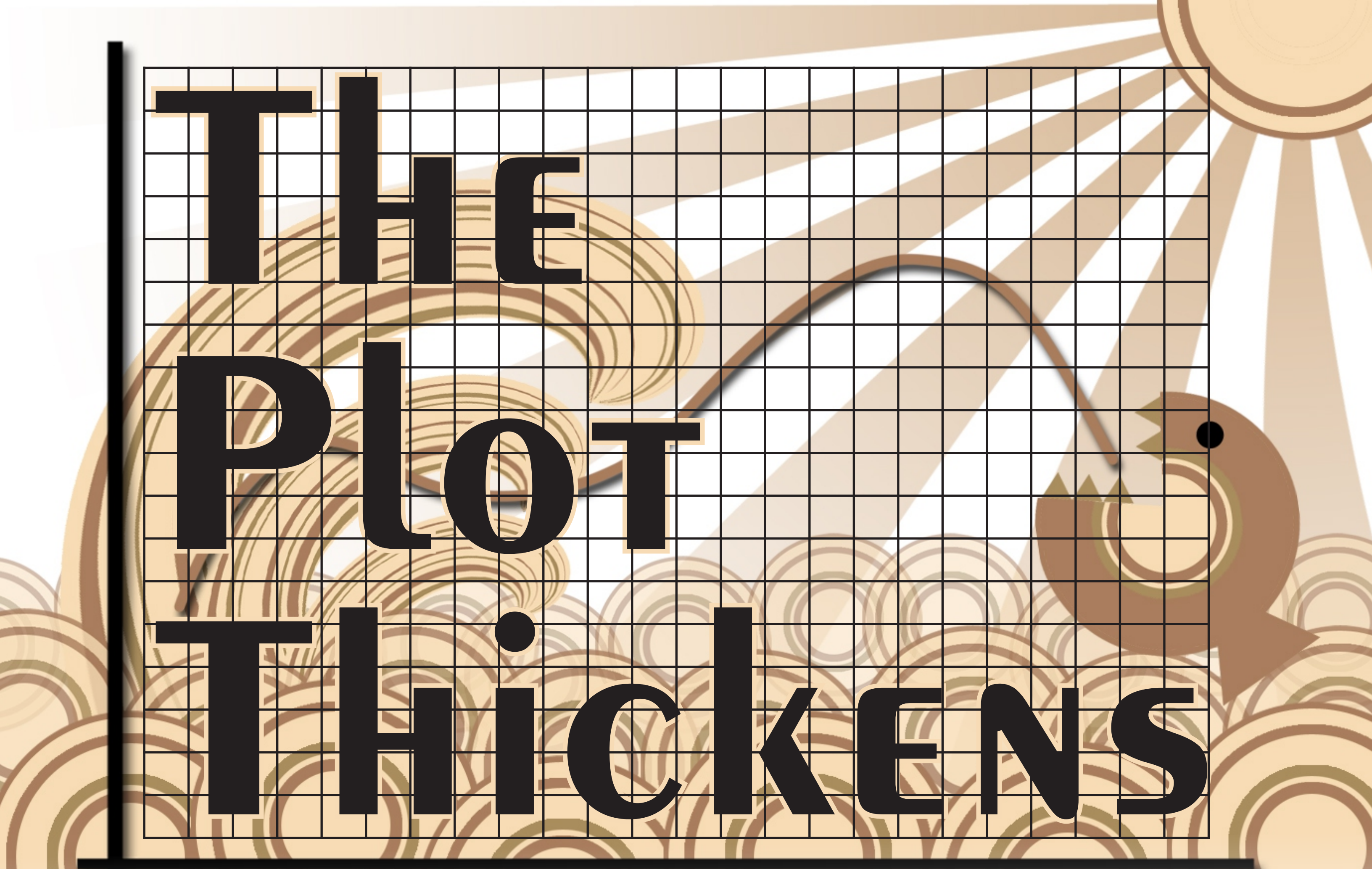
Iowa Science Teachers Journal

Volume 37 | Number 1 Article 4

2010

The Plot Thickens: Using a Plotting Activity to Start Your School Year Strong

Joe Taylor
Washington High School, Cedar Rapids



Graphic Work by Joe Taylor

USING A PLOTTING ACTIVITY TO START YOUR SCHOOL YEAR STRONG

Joe Taylor, Washington High School
Cedar Rapids Community School District

ABSTRACT: Captivating students and setting high expectations for critical thinking are two key classroom goals. This plotting and graphing activity is designed specifically to achieve these goals. Additionally, this activity can be modified for any science course taught at the secondary school level. Support materials including teacher and student printouts are provided at the end of the article. *This activity promotes National Science Education Standards A, C, D, and F and Iowa Teaching Standards 1, 3, 4, 5, and 6.*

Having students understand how science works is one of the most important goals for science education. For this reason, I begin the school year with an activity that has students making decisions, plotting data, discussing the meaning of data, and sharing results.

Beginning the school year on the right foot is crucial for creating and maintaining a productive and respectful classroom environment, and for making clear the science education goals we have for students. Importantly, the very way a course is conducted always conveys something to students about the subject matter and the course itself. Beginning the school year with activities that require very little from students sets a dangerous tone, and undoing unintended unproductive messages is difficult.

The activity described here regarding the plotting of data sends the clear message that science is about making sense of data, and that students will be expected to work hard and enjoy the fruits of their labor through deep learning and meaning-making. Importantly, I am not advocating that students ought think my class is tedious, but that they come to know the joy of hard work and deep thinking.

This activity lasts a minimum of two 30-minute segments, and can last several days based on what transpires. I come back to this activity again and again throughout the year, and revisiting it and the lessons learned are particularly amendable during those five to ten minute periods of time that are sometimes left at the end of a class period after completing the planned lesson. While I use this activity in the first days of my course, the activity could easily be placed almost anywhere in your curriculum.

Day 1

When students enter class, I assign them to teams of two. This group size encourages dialogue while maximizing on-task behavior. Each team is given one of the data sets (Figure 1 and Pages 14 and 15) and a sheet of 24x24 grid graph paper (Page 17). Students will later show their graphs to the class, so choose a medium that can easily be viewed by the entire class. Grids photocopied to transparency sheets work well, but I have also used large butcher paper or even large whiteboard cutouts. I have also connected a video camera to a projector or an ELMO projector, which allows teams to use regular sheets of graph paper.

I tell students that their first task is to graph the data on to their graph paper. Most teams will quickly organize themselves, identify a person to begin plotting the data, and begin the work. Inevitably, some teams will struggle to start. Two common reasons are that team members do not know each other and therefore no one initiates conversation, or team members lack confidence about how to set up the graph or plot the data.

During these first couple of minutes I walk throughout the room to identify which teams are productive and which are struggling to start. After identifying which teams are struggling, I do the following:

Nothing!

By nothing, I mean I do not *initially* approach a team. I do not interrupt the team to give them more direct instructions or tell them how to start. Instead, I stand a few steps from the team so that they are aware that I'm listening to their conversation. My proximity often spurs the team to talk more directly with each other. I avoid letting students off the hook and using me as a crutch. I am aware that struggling students will grow uncomfortable when I do not approach them to give them directions, but this is part of their learning process and conveys important implications about my expectations for them.

I continue to walk through the room and make mental notes about the progress teams are making. At times I will see students making a mistake in their technique or method of graphing. For instance, their data range may start at a large value, but they still start their graph value at zero or a team might use a scale that isn't appropriate for their data. I consider each instance and decide whether to allow the team to continue their mistake, or to step in and prevent the mistake from going too far. I base these decisions upon several factors such as what students might learn from their mistake, how we might use the mistake as a teachable moment for the benefit of the entire class, how much time it would take to correct the mistake once they realize the problem, and what I know about the abilities of the team members.

FIGURE 1
Sample data set for a student group.

X	Y	X	Y
1	12000	13	22000
2	15000	14	28000
3	19000	15	4000
4	17000	16	45000
5	22000	17	7500
6	26000	18	11500
7	5500	19	13500
8	8000	20	17000
9	11000	21	19500
10	14500	22	20000
11	18000	23	4500
12	20500	24	4000

See Pages 14 and 15 for all 16 data sets.

If I address a problem with the team, I use questions to direct the team members to the problem. For example:

- "If you continue plotting your data with each line equal to a value of two, what problem will you encounter when you go to plot the last section of your data?" Or
- "The purpose of creating a graph is to help visualize your data. If all of your data on the Y axis are between 6.5 and 7.5, how will starting your range at zero affect the ease of visualizing your graph?"

Teams will often ask whether they should create a bar graph, connect the lines, or just plot the points. I want my students to make these decisions themselves, so I respond by reminding them that the purpose of a graph is to help visualize data, and that they should choose the style of graph that they think will provide the best visualize. *See Nuts about Inquiry by Kasuga and Evans in the 36(3) issue for additional ideas about teaching students how to choose an appropriate graphing style.*

I monitor the class to see when most teams have plotted about a third of their data. Reaching this point usually takes about three or four minutes. I call out to the class in a moderate tone, "Stop!" The whole class looks up at me with wide eyes and jaws dropped thinking that I had expected them to have completed their work. Instead, I tell them to hand off the pencil/pen to someone else in the to continue the work. Students will look relieved and laugh at their own reactions to what they thought was me expecting them to finish so quickly. Interjecting humor into the learning process helps create the sense of a safe and flexible learning environment, while conveying the message that I am aware that in most teams only one person has been drawing the graph, and that I want each person to be involved.

I continue to monitor the class and pose questions to individual teams. At times, my questions are intended to direct students to particular areas of their graph, either to uncover potential problems or to determine whether they can explain the rationale behind their decisions. Questions that I often use include:

- "How did you determine the interval for each axis?"
- "How did you determine the minimum and maximum values for each scale?"
- "What decisions did your team need to make before beginning the graphing?"

When posing these questions, I have a heightened awareness of my tone of voice and non-verbal body language. Rather than standing over students, I often kneel down at their desk or even pull a chair up to discuss their graph. When discussing their work, I want students to see that I am genuinely interested in their efforts and thinking.

> While I am working with one group, I am careful to position myself so that I can still see the rest of the classroom. I do this so I can monitor the class, to include noting students with raised hands and to ensuring all students are on task.

My voice conveys a sense of curiosity, and I always take their responses and play off of them. For example, if a student answers the second question above by stating he/she looked for the smallest and largest number in the range, I might respond with

- "Some teams don't look at the minimum and maximum values and simply start their graph at zero. Why didn't you use that approach?" Or
- "Why did you decide not to leave extra room for new data at the top and bottom of your graph?"

When responding to their comments, I work carefully to promote deeper thinking. I carefully phrase my words to ensure that it is students who are doing the thinking. Students often answer either of the two questions above with "I don't know." It would be tempting to respond by suggesting a sample answer to the team. However, making the connection for students deprives them of the opportunity to make the connection themselves, leading to a weaker understanding (Appleton, 1997). Instead, I rephrase my question to make it more concrete. For example, I could rephrase the first question as "How would your graph look different if you had used zero as your minimum value on each axis?"

Teams will complete their graphs within ten or twenty minutes. Once I see that multiple teams are finished, I project the list of graph titles (Figure 2 and Page 16) up on the board. I have all teams stop their work and look at the board. I explain to the class that the list contains the title for each of the data sets, but that they have been scrambled. I tell the class that the next challenge is for each team to determine which title corresponds with their graph. I explain that they must not only work together to determine which title goes with their data, but that they must also present their decision to the class and offer convincing reasoning.

Once these directions are explained students typically have 5-10 minutes to work until the period ends. Once again I walk around the classroom to observe students' actions and conversations, avoiding interrupting a team unless they are off task or have misunderstood the directions. My experience has been that the majority of students thoroughly enjoy the challenge of figuring out which title goes with their graph. We end the class period with teams seeking out the best title for their graph. As the bell nears I explain to the class that we will continue this activity the next day and then I collect all teams' data tables and graphs.

> Always collect all teams' data sets and graphs at the end of class. I've learned the hard way the frustration resulting from a student taking their teams' papers home and forgetting it or being absent the next day. Students lose their motivation if they have to start the graphing over from scratch!

Day 2

I greet students as they enter the classroom and have them pick up their data sets and graphs and continue their work from yesterday. I often have students begin working before the bell rings. Consistently doing this results in both teacher and students habits that increases instructional time by minutes each day – and hours over the course of the school year (Clough, et. al., 1994)!

FIGURE 2
Graph Titles projected on the board

Population of tadpoles in a large pond
Density of green algae in a lake (grams per liter)
Total rainfall
Dissolved oxygen level (parts per million)
Average wind speed
Average number of aphis per plant
Ocean water temperature
Average cloud cover (%) [100% = always overcast]
Number of ducks observed at a state park
Daily rainfall

See Page 16 for a printable version.

Once all students are back in their teams and working together, I interrupt them long enough to explain the plan for this class period. Teams will have a predetermined length of time to finish determining their graph title. I'll suggest 10-15 minutes, but I do not mind extending this time if teams are engaged in productive discussion. I remind students that at the end of the work time we will alternate presenting in front of the class. A team will display their graph to the class, explain the visual elements of the graph (numbers, axes, patterns), and finally defend their graph title.

As students work together within their teams, I float through the classroom and listen to their conversations. There is always a wide variety of productivity, and I work quickly and efficiency to spur students to think deeply about the activity. For instance, some teams will think they have their title figured out within a couple of minutes and will want to move on to socializing. I use questions to help such teams dig deeper. Sample questions that I use include:

- "When looking at your graph, which titles did you rule out?"
- "What is your reasoning for ruling out this title?"

I look for inconsistencies or oversights in their answers to help the team members analyze their own reasoning. For example:

- "This title does not list its units of measurement. What units did you assume were used?" Followed by
- "Why might this assumption be problematic?"

Sometimes members within a team will be split as to which title matches their graph. I explain to the team that this is not only common, but desirable. Disagreement demonstrates that team members are thinking about the graph from unique perspectives, and the ensuing team discussion will help identify the strengths and weaknesses of each position. I also explain that they may not ultimately reach a consensus. If so, their responsibility when presenting is to have each team member summarize their position to the class.

While talking with teams I make a mental list of interesting discussion points that I want to see raised during the class presentations. Sometimes I will cue a team to specifically raise that point while presenting, or I will help raise the point during the presentations. For example, some of the data sets have an intentional outlier data point that sparks interesting discussion with the team, and can lead to lively discussion during the class discussion. I also identify and prompt a couple of teams to let them know I may call on them to present first.

If sticking within the 30-minute window for the second day of this activity, you will have approximately 10-15 minutes for presentations. Once the first team to present has been identified, we discuss several important rules of classroom conduct. First, I ask students

- "What are the responsibilities of the team who is presenting?"

Responses typically include (or need to be interjected) to present their graph, to identify patterns, to explain which title they think is correct, and to explain why they think they are right. I follow up this discussion with

- "What are the responsibilities of the audience?"

This is my first whole-class discussion of the year. I am careful to make sure I am providing extensive wait-time and encouraging more than one answer from the class for each of my questions. Rather than moving on after an answer, I continue to look around the room expectantly for additional student ideas. Sometimes I even count on my fingers to denote that I expect additional ideas. If students do not bring up all the points I am trying to make, I do not tell them what is expected, I ask a more pointed follow-up question such as I did above when I asked "What does someone who is paying attention say and do?" after asking "What are the responsibilities of the audience?"

Students will offer suggestions such as to remain quiet, to listen to the presenting team, to be respectful, and to keep focused. If it isn't raised by the class, I ask "What does someone who is paying attention say and do?" I want students to understand that each person must listen to the reasoning given by the presenting team, and be trying to identify problems or oversights that might affect the team's judgment. I also ask, "After a team has presented, what things would an attentive audience do?" After students note that they would ask questions and make comments, I tell them we will open the discussion to the entire class to evaluate their conclusions.

Finally, we have our first team presenting. This is where I have to be particularly attentive to identifying and prioritizing variables raised in the students' presentations. As a team presents, I am evaluating their presentation for each of the segments they are to include. I find that the first couple of presentations often breeze over important points, such as explaining what the graph visualizes and the reasoning for their conclusion. I am thinking about what interesting discussion points they have raised, and potential questions that could be posed to them. I am also monitoring the class to ensure all students are giving the presenters their full attention. When a student in the audience is off task, I keep my eyes trained on the presenters and casually move to stand near the offender and let the power of proximity encourage him or her to re-engage.

There are two things that I do not want to happen during class discussions. The first is that I do not want my class to wait in silence for someone else (especially me) to carry the burden of talking. The second is that I do not want the same students consistently doing all of the talking. Especially during the start of the term I am careful to discuss with my classes the need and value of whole class participation.

Once the team has finished, we turn the discussion over to the class. Sometimes I will prompt the presenting team to end their presentation with the question "What questions to you have for our team?"

Class response varies widely from period to period and from year to year. Students are often not accustomed to a classroom environment of open discussion. Sometimes a small number of students in the audience will raise their hands and a discussion is initiated, but this isn't always the case. During the span of time immediately after the presenters ask for questions, my role as the teacher becomes even more important.

I use eye contact and an inquisitive smile to create a sense of expectancy for the class. This often is effective in compelling students to get involved. If not, I will introduce a quick "time out" to discuss how to prepare oneself for participation. For instance, we discuss how it is ok if you do not initially have a question in mind, but a responsible learner will reflect upon the team's presentation and seek out questions or points to discuss.

The class discussion can go in a multitude of directions based upon what questions or points were raised. I keep a pad of paper nearby to keep a record of topics that we address, which I can then refer back to later in the term. I also keep a list of possible questions at hand in the event that students struggle to raise their own questions. For example:

"When viewing data, what is an advantage of a graph over a data table?"
"The title you chose didn't state its units. How did this affect your process of selecting a title?"
"Why must a graph include x and y labels and a title?"
"What decisions did your team discuss during this activity?"
"How did you resolve disagreements within your team?"
"If you were to start this activity over, what would you keep the same and what would you do different?
"What is the value of presenting and discussing with the entire class?"
"How is what our class did during this activity similar to the work of scientists?"
"How is it different from the actual work of scientists?"

Part of the power and success of this activity is in its flexibility. Each team presentation typically lasts between 5 and 10 minutes. I do not rush the presentations, and we may get through only 2 or 3 presentations in the class period. I don't feel it is necessary to have every team present, so there is a lot of flexibility in how many times you come back to this activity. While in this article I discuss only the initial two days of the activity, in my classroom I extend it much further. Some days I plan in advance a few minutes for another team to present. This activity also helps to fill the last few minutes of a class period when you complete another lesson early and need to provide your students with meaningful work until the bell rings.

Why Do This Activity?

My intent with this activity is twofold. First, this activity helps establish the sort of learning environment that includes critical thinking, collaboration, creativity, and a mindset of inquisitiveness. Students develop an understanding that in this classroom we discuss ideas, we evaluate their merits, and we respectfully challenge each other to consider the strengths and weaknesses of any given argument. Second, this activity lays down the first layer of scaffolds to which I can later refer back. Some important ideas promoted by this activity include:

1. The steps for creating a graph from a data table.
2. A graph is a tool to help visualize data and to more easily identify possible patterns.
3. Working in teams is a valuable way to uncover multiple viewpoints.
4. Making mistakes is an expected part of the process of learning.
5. Valuable ideas arise when we discuss them in teams.
6. A given problem may have no clear single solution.
7. Good reasoning is an essential part of supporting a conclusion.
8. The work we do in class shares many similarities with the actual work of scientists.

Students often have misconceptions about science. Students will need help understanding how this activity models real science and the work of actual scientists. My role as the teacher is to help students make explicit connections between the activity and science. McComas (1996) describes many common misconceptions held by students. Below is a partial list of some of the student misconceptions and sample questions that you could address with students.

Many students incorrectly believe that:

1. Careful analysis of data will lead to one correct scientific solution.
   - "What aspects of this activity challenge the idea that there must be one correct interpretation of data?"
   - "How might we apply this to the work of real scientists?"
2. A scientist is absolutely objective when analyzing data.
   - "An objective point of view is one in which no personal bias or prior ideas is allowed to influence your work. What are some examples from this activity that show it is impossible to choose a graph title from an objective point of view?"
   - "Why would this also be the case for scientists?
3. The development and acceptance of scientific knowledge is fairly straightforward.
   - "What disagreements did you have to resolve within your team or during our class discussion?
   - "How would you respond to someone who thinks that doing science is little more than doing an experiment, collecting data, and writing down the answer?
4. Discussion about the interpretation of data amongst scientists is largely unnecessary since scientists usually just work alone.
   - "How would your results have been different if you had to work alone and we had no class discussion?
   - "How do you think we could apply this idea to science or the work of scientists?

Were We Right?

This is the most often asked question from students during and after this activity. When it is asked during the activity, I tell the student that his/her question is valuable, and to pay attention throughout the activity to see if it is answered to his/her satisfaction. What students come to realize is that I never provide them with an answer key.

While this invokes frustration in some students, the decision to not provide an answer key illustrates an important characteristic of science and scientific knowledge. Many aspects of the natural world cannot be described in any absolute sense. A scientist might propose an explanation about, for example, the structure of an atom or the distant history of our solar system. In such cases, the purpose of using a scientific approach is not to determine (or prove) some absolute and true explanation about the essence of the natural world. Science does not accomplish this. Instead, science provides a way of developing an explanation that is based in evidence, reasoning, and testing. But at no time can a scientist take a proposed explanation and go look somewhere to see if he or she has the right answer. Nature is not revealed in this way.

While this is an abstract idea for students, it is a valuable idea to help them understand. If students are left thinking that science is doing laboratory tests until we get the right answer, they will perceive science as boring, devoid of creativity, and uninteresting. When students get past this hurdle they feel the freedom to use science as a tool that compliments their natural curiosity, inquisitiveness, and resolve to pursue their questions with an open mind.

You will likely notice that I have not included in this article an answer key to match the data sets to the graph titles. When I developed this activity I compiled a list of graph titles, and then created plausible data sets to accompany each title. In fact, you will notice that there are more data sets than there are graph titles. I no longer go back and look at the original order of graph titles that I created so that I myself will not steer my students toward a particular solution. This helps keep the activity fresh for me, and also compels me to play by the “rules” of science.

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Joe Taylor is a science teacher at Washington High School in Cedar Rapids. In his five years of teaching he has taught Biology, Astronomy, Geology, and Meteorology. Joe has also served as the Managing Editor of the Iowa Science Teachers Journal since its revitalization in 2005. Contact Joe at joetaygtg@gmail.com with questions about this article or to receive additional tips for how to successfully implement this activity with students.

Data Set #1	
X	Y
1	17.4
2	17.9
3	18.7
4	19.3
5	20.4
6	20.5
7	20.1
8	19.5
9	18.8
10	18.5
11	18.2
12	17.5
13	16.0
14	15.4
15	14.8
16	13.9
17	13.6
18	13.7
19	13.9
20	14.4
21	14.8
22	15.7
23	16.4
24	17.1

Data Set #2	
X	Y
1	16.1
2	14.7
3	12.5
4	10.6
5	8.8
6	7.8
7	7.9
8	8.6
9	8.9
10	10.3
11	13.2
12	15.1
13	16.3
14	15.7
15	12.8
16	10.5
17	8.4
18	8.5
19	7.8
20	8.3
21	8.7
22	10.1
23	12.9
24	14.9

Data Set #3	
X	Y
87	42.5
88	41
89	42
90	42.5
91	41
92	41
93	38
94	32
95	26
96	24
97	23.5
98	29
99	41
00	44
01	46
02	43.5
03	40
04	41
05	37.5
06	35
07	29
08	26
09	25.5
10	28

Data Set #4	
X	Y
1	12000
2	15000
3	19000
4	17000
5	22000
6	26000
7	5500
8	8000
9	11000
10	14500
11	18000
12	20500
13	22000
14	28000
15	4000
16	45000
17	7500
18	11500
19	13500
20	17000
21	19500
22	20000
23	4500
24	4000

Data Set #5	
X	Y
1	80.4
2	81.2
3	80.9
4	81.8
5	81.8
6	80.8
7	80.9
8	80.5
9	82.1
10	81.9
11	28.1
12	82.7
13	81.7
14	82.3
15	81.2
16	81.4
17	80.6
18	81.0
19	81.0
20	81.6
21	82.3
22	82.0
23	82.5
24	82.6

Data Set #6	
X	Y
1	72
2	78
3	65
4	66
5	74
6	72
7	72
8	68
9	64
10	71
11	70
12	82
13	75
14	73
15	76
16	67
17	73
18	75
19	68
20	66
21	82
22	69
23	71
24	63

Data Set #7	
X	Y
2	5
4	6
6	6
8	5
10	6
12	7
14	7
16	8
18	6
20	6
22	6
24	5
26	6
28	6
30	7
32	6
34	5
36	6
38	7
40	7
42	8
44	8
46	8
48	9

Data Set #8	
X	Y
Su	7.2
Mo	7.3
Tu	7.3
We	7.4
Th	7.2
Fr	6.9
Sa	6.8
Su	6.7
Mo	6.8
Tu	6.8
We	6.7
Th	6.6
Fr	6.7
Sa	6.6
Su	6.6
Mo	6.8
Tu	6.7
We	6.8
Th	6.8
Fr	6.8
Sa	6.9
Su	7.0
Mo	6.9
Tu	7.0

Data Set #9	
X	Y
1	6.51
2	6.60
3	6.55
4	6.47
5	6.30
6	5.94
7	5.68
8	18.00
9	5.71
10	5.99
11	6.25
12	6.49
13	6.61
14	6.59
15	6.50
16	6.46
17	6.29
18	5.90
19	5.64
20	5.52
21	5.58
22	5.96
23	6.27
24	6.54

Data Set #10	
X	Y
08	14.2
09	14.8
10	13.5
11	13.6
12	14.4
13	14.2
14	14.2
15	13.8
16	13.4
17	14.1
18	14.0
19	15.2
20	14.5
21	14.3
22	14.6
23	13.7
24	14.3
25	14.5
26	13.8
27	13.6
28	15.2
29	13.9
30	14.1
31	13.3

Data Set #11	
X	Y
1	0.00
2	0.00
3	2.35
4	3.71
5	4.19
6	4.19
7	4.23
8	5.78
9	7.97
10	7.97
11	7.97
12	7.97
13	11.60
14	14.21
15	13.78
16	14.17
17	14.17
18	16.44
19	16.45
20	18.23
21	18.79
22	18.79
23	19.45
24	19.89

Data Set #12	
X	Y
1	12
2	25
3	78
4	45
5	100
6	67
7	85
8	25
9	10
10	92
11	43
12	0
13	55
14	34
15	79
16	19
17	0
18	45
19	24
20	96
21	24
22	76
23	35
24	81

Data Set #13	
X	Y
1	14.4
2	13.9
3	14.4
4	15
5	16.1
6	17.8
7	18.9
8	20
9	18.9
10	18.3
11	16.1
12	15
13	13.9
14	13.9
15	14.4
16	15
17	16.1
18	17.2
19	18.9
20	20.6
21	19.4
22	18.3
23	16.1
24	14.4

Data Set #14	
X	Y
1	5900
2	6050
3	6100
4	6100
5	6150
6	6200
7	4200
8	4250
9	4300
10	4400
11	4650
12	4900
13	5300
14	5550
15	5700
16	5800
17	5950
18	6000
19	6050
20	6050
21	6100
22	6150
23	6150
24	6200

Data Set #15	
X	Y
87	87.2
88	62.1
89	99.4
90	110.0
91	84.9
92	56.4
93	60.4
94	80.0
95	90.6
96	122.0
97	105.3
98	87.4
99	56.6
00	0.0
01	82.2
02	115.7
03	67.9
04	70.5
05	88.3
06	82.6
07	93.8
08	101.5
09	73.6
10	99.3

Data Set #16	
X	Y
1	0
2	0
3	0
4	0
5	3
6	12
7	19
8	38
9	95
10	127
11	179
12	192
13	195
14	194
15	127
16	95
17	57
18	28
19	19
20	14
21	0
22	0
23	0
24	0

Graph Titles:

Population of tadpoles in a large pond
Density of green algae in a lake (grams per liter)
Total rainfall
Dissolved oxygen level (parts per million)
Average wind speed
Average number of aphids per plant
Ocean water temperature
Average cloud cover (%) [100% = always overcast]
Number of ducks observed at a state park
Daily rainfall

Graph Titles:

Population of sharks per 10 cubic kms of water
Density of surface plankton (grams per liter)
Total rainfall (mm)
Dissolved oxygen levels (ppm – parts per million)
Populations of Rockfish (small fish) per cubic km
Ocean acidity (pH)
Ocean water temperature
Average cloud coverage (%) [100%=always overcast]
Dissolved carbon dioxide levels (ppm)
Amount of solar radiation

Note: The second list of Graph Titles is the author's original list created for an Oceanography/Meteorology course. Either list can be used with the data sets provided in this article.