

Teacher's Guide

Using A Volunteer Acquired Database Constructed On The Internet, Examine the Relationship between Dissolved Oxygen and Water Temperature

Lesson Description

The relationship between dissolved oxygen and water temperature is critical for aquatic life in a stream, river or lake. More dissolved oxygen is present in water with a lower temperature compared to water with a higher temperature.

The reason for this inverse relationship between dissolved oxygen and temperature is that the solubility of a gas in a liquid is an equilibrium phenomenon. According to La Chatelier's Principle, any reaction reaching equilibrium will seek a new equilibrium when a variable (temperature) influencing that equilibrium is altered.

This gas solubility in a liquid relationship can be further clarified if you think about what happens to a cold carbonated beverage; as it is opened and stands around for a while at room temperature. Once warmed to ambient temperature the taste is very "flat"; since more of the "tangy"; carbon dioxide bubbles have escaped. Boiled water also tastes "flat" because all of the oxygen gas has been removed by heating. More dissolved oxygen is present in water with a lower temperature compared to water with a higher temperature.

Given the two variables of dissolved oxygen and temperature with a possible linear relationship, an analysis of the relationship is possible by plotting both variables on a graph as part of an XY scatter plot. Using MS Excel spreadsheets, it is very easy to do this. Using either Excel or a graphing calculator, calculate the correlation coefficient, conduct a linear regression on the data, and find the given r-squared value along with the "best-fit-line" equation.

The correlation coefficient = r is a value between negative 1 and positive 1. The closer the value is to -1 and +1, the better the predictability of the relationship. If $r = -1$, there is a negative slope and if $r = +1$ the r -value represents a positive slope or positive relationship. Variables with r -values close to 0 represent no relationship.

R squared represents the % change in the dependant variable that can be contributed to the independent variable. If r-squared is 0.88, then 88% of the change in the dependant variable is attributed to a change in the independent variable. Most of the time, multiple variables will affect the given variable as is the case of water temperature and dissolved oxygen. In brief, **r squared is the relative predictive power of a model.** The value of r squared (r^2) is a descriptive measure between 0 and 1. **The closer it is to one, the better your model.** By "better" we mean a greater ability to predict. A value of r squared equal to one (which only occurs in fairy tales and textbook exercises), would imply that the linear regression provides perfect predictions, and the more the two variables are related. As the r-squared value gets closer to zero, the less the two variables are related and the less reliable the regression equation will be for purpose of making predictions

Science Concepts Introduced

Making predictions from data previously collected and analyzed for their correlation.

Process Skills Emphasized

- Internet retrieval of a specific database
- Interpreting data
- Applying statistics
- Computer analysis

Technology Used

- Internet
- MS Excel using the correlation function.

MST Standards

Standard 2 Key idea 1

Standard 3 Key Idea 6

Standard 4 The Living Environment Key Idea 5

- **Living Environment 5**
- **Physical Setting/Earth Science 2 & 7**

Learning Outcomes

Students will be able to:

- Access the Project Watershed database at <www.projectwatershed.org>.
- Open a spreadsheet, copy and paste (download) the values to be investigated.
- Save the original database and make a backup copy.
- Sort the data by stream, by date, or by location.
- Find the correlation between water temperature and dissolved oxygen.
- Generate scatter plot graphs.
- Prepare a report describing their findings for the dissolved oxygen/water temperature correlation.

Time Requirement

2-4 class periods or 2 blocks (dependant upon student skill level using the Internet, spreadsheets and graphing programs).

- Class period one: accessing and exploring the database at <www.projectwatershed.org>
- Class period two: downloading selected data, placing it in a MS Excel spreadsheet, and manipulating the data using the MS Excel correlation, formula and chart functions.
- Class period three: preparation of a statistical report by student groups with class discussion on the understandings formed and/or anomalies observed.

Instructional Strategies

- Cooperative learning groups
- Individual learning
- Statistical inquiry

Background

When downloading information from the website, it is necessary to select for MS Excel format. Students will need to enter the correlation formula and highlight two columns of variables to determine if a relationship exists. Students will also highlight two columns in order to use the Chart functions to produce a graph of the selected variables. The primary focus of this exercise

is to have students examine the variables, dissolved oxygen and water temperature. Once they have learned how to use MS Excel to examine these selected variables, they will be able to use the same procedures to examine any pair of selected variables.

The reference section of this lesson contains a number of links to web pages that provide computer directed instruction in the use of spreadsheets, graphing, and finding correlations. Since instruction in spreadsheet use is primarily procedural, it is recommended that a strategy of demonstration followed by guided practice be employed.

Because the process of data collection is inherently flawed, students will find that the observed results of their investigation may differ strikingly from their expected results. This provides an excellent opportunity to stress the importance of accuracy and precision whenever data is collected. In addition, it should be emphasized that there are many variables other than water temperature that can affect dissolved oxygen concentration. Because the expected relationship is based upon controlled laboratory measurements, interfering variables such as those found in field collected data are not present. This provides an excellent opportunity for students to consider what other factors could be altering dissolved oxygen concentrations from their expected levels.

Assessment

1. Students demonstrate their competence for the learning outcomes as follows:
 - Access the Project Watershed database and download selected data by copying and pasting selected data into a spreadsheet.
 - Prepare a graph(s) from teacher designated sets of data using default formatting.
 - Derive the correlation coefficient of data by using the statistical formula functions for correlation in a spreadsheet.
 - Perform a self-directed search of the Project Watershed data and report on the findings. (Findings must include copies of the data selected, graphs and statistical findings applied to the data.)
 - Put forth conclusions based on their findings and provide possible explanations and/or suggestions for further data collection or analysis to satisfy their search.
2. Student groups will be responsible for developing a report on their findings for presentation to the class.
3. Students take part in a class discussion of their data as well as their interpretations, and conclusions relative to the database and the statistical and graphic tools they used.

Rubric for statistical correlation and graphic applications:

100 points with suggested point distribution as follows:

- 10 points for successfully accessing the online database
- 10 points for successfully copying and pasting data in a spread sheet
- 15 points for entering and using the correlation formula in the spread sheet
- 15 points for producing a scatter plot graph of the variables using the chart menu
- 20 points for interpreting the statistical correlation in a written report
- 20 points for interpreting the graph produced in a written report
- 10 points for the presentation of findings to the class.

Extensions/Options

- Use graphic and statistical techniques to perform additional self-directed searches of the Project Watershed database to examine other sets of paired variables for possible correlation.
- Student groups use the paired variables for analysis of different streams or seasons. Find variables with the highest correlation. Ultimately, students will gain confidence in using MS Excel spreadsheets as a way to prospect for potential relationships between other paired variables.
- After investigating the database in this lesson, students should be encouraged to participate in a stream sampling experience.

Key Terms

Dissolved oxygen, correlation, variable, database, coefficient, r-value, linear regression, best-fit-line and scatter plot.

Pre-Requisite Knowledge

- Skill in computer use is desirable but could be taught by assigning more time for this lesson.
- Knowledge of the relationship between gas solubility and solvent temperature, presented formally in previous classes, or informally by using a simulation or an analogy.

Equipment Needed

A computer connected to the Internet.

References/Websites

Interpretation of graphs and statistical findings:

1. Scatter plot, line graph and/or correlation information:

<http://www.mste.uiuc.edu/courses/ci330ms/youtsey/scatterinfo.html>

<http://www.itl.nist.gov/div898/handbook/eda/section3/scatterp.htm>

<http://noppa5.pc.helsinki.fi/koe/corr/cor7.html>

2. Scatter plot and line graph with excel instructions:

<http://www.ncsu.edu/labwrite/res/gh/gh-linegraph.html>

3. Line graphing

<http://www.mste.uiuc.edu/courses/ci330ms/youtsey/lineinfo.html>

4. Correlation

Using Excel spreadsheets to find statistical correlation between two sets of data.

- a. Choose a cell where you want to display the results.
- b. Enter an equal sign, then “correl”, and a left parenthesis. ex. =correl(
- c. Describe the range of values for the first variable: ex. =correl (b2:b85
(This describes the series of values for the first variable in column b from cell number 2 to cell number 85.)
- d. Next type a comma (,) and then the range for the second value P.
ex. = correl (b2:b 85,d2:d85)

In this example, you are looking for the correlation between the values for first variable listed in column b, rows 2 through 85 and the values for the second variable listed in column d, rows 2 through 85. When you complete entering the formula, hit return and the numerical value for the correlation should appear.

Correlation describes how much one variable is affected by another variable. If the dependent variable increases in proportion to the increase of an independent variable, the relationship is described as a positive correlation. If the dependent variable increases in proportion to the decrease of an independent variable, the relationship is described as a negative relationship. The formula for correlation produces a number from -1 to +1. The number 1 indicates a perfect correlation and sign indicates whether the relationship is positive or negative. To see graphic representations of this, visit the following website <<http://www.mste.uiuc.edu/courses/ci330ms/youtsey/scatterinfo.html>>

Handouts

Project Watershed Correlation Of Two Variables Dissolved Oxygen vs. Water Temperature

A. Importing Data:

1. Go to <http://www.projectwatershed.org>
2. Click on the database icon
3. Click on Browse Data By Stream.
4. Select the parameters you wish to view in this lesson; they will be dissolved oxygen and water temperature.
5. Click on the stream you would like to study.
6. Finally Click on Submit
7. Copy and paste this information into an Excel Spreadsheet. (You may have to re-format your row and column dimensions to make it look good. Do this by highlighting all columns used, and go to the format menu.)
8. Save and print out this sheet. Highlight all data and make sure you “set print area”.

B. Graphing Your Data:

- 1.) Highlight all your numerical data. (Make Dissolved Oxygen the X-Variable and water temperature the Y Variable.)
- 2.) Click on the Chart Wizard in the menu bar.
- 3.) Choose the XY Scatter Plot as your graph.
- 4.) Go through the process making sure you have a key, label both axis and also include a title.
- 5.) Format your graph any other way you wish and create it as a “New Sheet”
- 6.) Save and print out this graph. (All you need to do is click on the graph and hit print.)

C. Getting the Best-Fit-Line:

- 1.) While looking at the chart, go to the Chart Wizard drop down menu and choose “Add trend line”.
- 2.) Choose Linear (Should be the default).
- 3.) Click the options tab in this window and select “To display the equation and the r^2 value on the chart”.
- 4.) Save the graph and print a copy.

Complete the following questions, staple all copies to this sheet and hand in. Make sure your name is on all copies!

Directions: Answer the following for your graphs concerning the relationship between dissolved oxygen and water temperature.

- 1) Best-fit-line equation: _____
- 2) What is your r^2 value? _____
- 3) What is your r-value (Correlation Coefficient)? _____

- 4) Explain in words what the correlation coefficient (r) says about the relationship between these two variables. What is/are “good” r -value(s)?

- 5) Knowing that the equation of all lines in the form $Y = mx+b$ has a slope of m and a Y -Intercept of b , what is the slope and the Y -Intercept of your best-fit line?

- 6) Interpret these values. What does the slope say about the rate each changes? What can you say about the Y -Intercept?

- 7) Knowing an equation that represents a pattern of data allows us to make predictions about one variable when we know the value of the other. Assuming the temperature in your stream is 20 degrees Celsius, what would you predict the dissolved oxygen level to be?

Data for Hand held Graphing Calculators If No Internet is Available

	Date		Dissolved O2 (mg/L)	Water Temp (C)
Limestone Creek, Kirkville Rd. Bridge Crossing	5/22/1995	2449860	4.7	18
Limestone Creek, Kirkville Rd. Bridge Crossing	10/23/1997	2450745	8	7.7
Limestone Creek, Kirkville Rd. Bridge Crossing	1/29/1998	2450843	12.5	4.2
Limestone Creek, Kirkville Rd. Bridge Crossing	5/20/1998	2450954	7.1	23.3
Limestone Creek, Kirkville Rd. Bridge Crossing	10/9/1998	2451096	8.6	14.4
Limestone Creek, Kirkville Rd. Bridge Crossing	6/8/1999	2451338	6.5	22.1
Limestone Creek, Kirkville Rd. Bridge Crossing	10/8/1999	2451460	4.7	11.2
Limestone Creek, Kirkville Rd. Bridge Crossing	2/24/2001	2451965	9.4	2
Limestone Creek, Kirkville Rd. Bridge Crossing	10/19/2001	2452202	9.7	12.3
Limestone Creek, Kirkville Rd. Bridge Crossing	4/5/2002	2452370	10.5	5.8
Limestone Creek, Kirkville Rd. Bridge Crossing	10/24/2002	2452572	10.2	8.8
Limestone Creek, Kirkville Rd. Bridge Crossing	10/17/2003	2452930	8.9	11.6
Limestone Creek, Kirkville Rd. Bridge Crossing	10/21/2004	2453300	9.6	10.8
Limestone Creek, Mill Run Park	6/5/1997	2450605	8.9	20.1
Limestone Creek, Mill Run Park	10/28/1998	2451115	9.5	12.4
Limestone Creek, Mill Run Park	5/3/1999	2451302	10.6	14.2
Limestone Creek, Minoa Shepps Corners Rd--Smith's Market	10/23/1997	2450745	10	7.3
Limestone Creek, Pleasant Street service road by former Manlius STP	7/9/2002	2452465	9.2	19
Limestone Creek, Pleasant Street service road by former Manlius STP	8/20/2002	2452507	7.9	20.3
Limestone Creek, Pleasant Street service road by former Manlius STP	10/10/2002	2452558	10.4	14.2
Limestone Creek, Pleasant Street service road by former Manlius STP	6/7/2003	2452798	8	14
Limestone Creek, Pleasant Street service road by former Manlius STP	7/8/2003	2452829	7.8	21.5
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	6/15/1995	2449884	10	18
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/23/1997	2450745	9.6	7.7

Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	1/29/1998	2450843	11	3.3
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	5/20/1998	2450954	8.8	21.7
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	5/29/1998	2450963	11	3.3
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/9/1998	2451096	9.5	14.1
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	6/8/1999	2451338	7.4	23.5
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/8/1999	2451460	10.5	9.5
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/23/2000	2451841	10.8	9.1
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	2/24/2001	2451965	13.2	1.7
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/19/2001	2452202	10.9	10.1
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	4/5/2002	2452370	12.5	3.9
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/24/2002	2452572	11.2	7.2
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/17/2003	2452930	10.5	9.5
Limestone Creek, Rte. 5 Bridge Crossing, Fayetteville/Town Hall	10/21/2004	2453300	10.3	9.6

Student's Guide

Using A Volunteer Acquired Database Constructed On The Internet, Examine the Relationship between Dissolved Oxygen and Water Temperature

Lesson Introduction

The relationship between dissolved oxygen and water temperature is critical for aquatic life in a stream, river or lake. More dissolved oxygen is present in water with a lower temperature compared to water with a higher temperature.

The reason for this inverse relationship between dissolved oxygen and temperature is that the solubility of a gas in a liquid is an equilibrium phenomenon. According to La Chatelier's Principle, any reaction reaching equilibrium will seek a new equilibrium when a variable (temperature) influencing that equilibrium is altered.

This gas solubility in a liquid relationship can be further clarified if you think about what happens to a cold carbonated beverage as it is opened and stands around for a while at room temperature. Once warmed to ambient temperature the taste is very "flat"; since more of the "tangy"; carbon dioxide bubbles have escaped. Boiled water also tastes "flat" because all of the oxygen gas has been removed by heating. More dissolved oxygen is present in water with a lower temperature compared to water with a higher temperature.

You will be investigating the co-relation of two sets of values given in the Project Watershed database. By using a statistical application of a computer spreadsheet, you can determine the effect of temperature on the ability of water to capture and retain dissolved oxygen.

You will download dissolved oxygen and temperature data into a MS Excel spreadsheet. There are two MS Excel tools you will be using.

Tool 1: Statistical Correlation

Correlation indicates positive or negative association between variables. Two variables are positively associated when the largest values of one are accompanied by largest values of the other. Two variables are negatively associated when the largest values of one are accompanied by the smallest values of the other. Correlation tests describe how strongly the two scores are associated or correlated with each other. In this lesson, you will examine the variables of dissolved oxygen and water temperature to determine if a correlation exists between these two variables. Correlation is measured between negative 1.0 and positive 1.0. Correlations approaching 0.0 (middle of the range) indicate little or no relationship. Correlations close to +1.0 indicate strong positive relationships. Correlations close to -1.0 indicate strong negative relationships.

With a vast amount of laboratory testing and measurement showing a strong negative correlation between dissolved oxygen and water temperature, you will have the opportunity to examine this relationship on field collected data. By examining how well the real field data demonstrates the ideal laboratory relationship between dissolved oxygen and water temperature you will be able to identify the strength of the correlation. .

Tool 2: Graphing

Using the chart menu in an Excel spreadsheet, you will make graphs of the two variables - dissolved oxygen and water temperature. You will be looking for patterns of plotted points such as a straight line or a scatter of points that appear to slope upward or downward.

A grouping of points which seem to slope from left to right indicates a positive correlation, and one which slopes from right to left indicates a negative correlation. Once the best-fit-line is produced it will be possible to predict the ideal levels of dissolved oxygen at any temperature between zero and one hundred.

Learning Outcomes

Students will be able to:

- Access the Project Watershed database at <www.projectwatershed.org>.
- Open a spreadsheet, copy and paste (download) the values to be investigated.
- Save the original database and make a backup copy.
- Sort the data by stream, by date, or by location.
- Find the correlation between water temperature and dissolved oxygen.
- Generate scatter plot graphs.
- Prepare a report describing their findings for dissolved oxygen/water temperature correlation.

Skills Required

- Basic knowledge of spreadsheet statistical functions
- Interpreting data
- Graphing using spreadsheets or graphing calculators

New Terms

Dissolved oxygen, correlation, variable, database, coefficient, value, linear regression, best-fit-line, and scatter plot.

Quest

You are a forensic ecologist studying stream water quality data included in the Project Watershed database. From past experience, you have learned that an increasing water temperature during the summer can adversely affect the fish population in a stream, causing them to surface and "gasp for air."

After deducing that a lack of dissolved oxygen is the most likely cause of their distress, you implement a study of the dissolved oxygen and water temperature in Limestone Creek to seek a statistical correlation between the two parameters, and the possibility of a potential "fish kill." If a correlation is found between dissolved oxygen and water temperature, your next task will be to determine what water quality factors (positive or negative) that caused the changes in the dissolved oxygen concentration in the creek. And you will finally predict the temperature that will induce stress in the general fish population (gulping for air) and what temperature you would then expect the death of fish to occur.

Materials:

- A computer with Microsoft Excel
- Internet connection
- MS Excel

Procedure

1. Divide into groups of three to five students. The students will use dissolved oxygen and water temperature data collected at Limestone Creek.
2. Access the Project Watershed database website and select the dissolved oxygen and water temperature for all years. Copy the data and paste it in an Excel Spreadsheet.
3. In an empty cell next to the two columns of data, type “= correl (This informs the program of what formula you intend to use).
4. Then, holding the mouse button down, highlight the first column of data. (This will appear as “array 1” in the formula cell).
5. Next, **holding the control key down**, use the mouse to highlight the second column of data. To finish, return to the formula cell and type a “)” to finish the formula. It should look like the following: **=CORREL(H2:H326,G2:G326)**.
 - a. “correl” directs the program to find the correlation.
 - b. Brackets “()” enclose the data to be used in the calculation.
 - c. “H2:H326” describes the range of the first variable starting with cell H2 and going to cell H326, including all data cells between.
 - d. “G2:G326” describes the range of the first variable starting with cell G2 and going to cell G326, including all data cells between.
6. When you type in the last “)”, hit “Enter”, and the value for the correlation will appear.
7. To create a graph of the two variables, highlight the entire column for one variable by clicking on the capital letter at the top of the spreadsheet column. This designates that the numerical data entries in that column will be used. **While holding down the control key**, click the letter at the top of the second column. For this procedure, the two columns selected should be water temperature and dissolved oxygen.
8. Go to the control bar at the top of the page and select Chart Wizard. (It looks like a small, multicolored bar graph with 4 vertical bars). Select the “XY (Scatter)”. Follow the instructions at the bottom of the Chart Wizard window by clicking on “Next”. The third window allows you to label the X and Y-axes of your graph.
9. When the graph is finished, go to the control bar and the top and select “Chart” to view the pull down menu. Next select “add Trend line”. When the new window appears, select the “Linear” and push enter. A trend line appears which is the “best-fit” line for the points on the graph. In effect, it averages all the data to find the best possible, single line to represent all the points, regardless of how scattered they are.
10. Repeat the action in step 7. When you have the window, click on the tab, which says “Options”. This will cause a new window to appear. At the bottom of the window are three boxes you can select. Select “Display equation in chart”. This will give the formula of the line drawn in the form, $Y = mx + b$. The slope of the line will indicate a possible relationship even if the correlation formula did not. Select “Display r-squared value on chart” and you will get a value for r^2 . For example, an r^2 value of .65 is interpreted as, “changes in the first variable are responsible for 65% of the changes in the second variable”.

11. Print your graph. Be sure to include the correlation value, the formula for the trend line, and the value of r^2 .
12. When you have completed investigating the water temperature and dissolved relationship, select two other variables for study, and follow the same procedure for these new variables as you did above.

Extension/Options

- Use graphic and statistical techniques to perform additional self-directed searches of the Project Watershed database to examine other sets of paired variables for possible correlation.
- Student groups use the paired variables for analysis of different streams or seasons. Find variables with the highest correlation. Ultimately, students will gain confidence in using MS Excel spreadsheets as a way to prospect for potential relationships between other paired variables.
- After investigating the database in this lesson, students should be encouraged to participate in a stream sampling experience.

References/Websites

Interpretation of graphs and statistical findings:

1. Scatter plot, line graph and/or correlation information:

<http://www.mste.uiuc.edu/courses/ci330ms/youtsey/scatterinfo.html>

<http://www.itl.nist.gov/div898/handbook/eda/section3/scatterp.htm>

<http://noppa5.pc.helsinki.fi/koe/corr/cor7.html>

2. Scatter plot and line graph with excel instructions:

<http://www.ncsu.edu/labwrite/res/gh/gh-linegraph.html>

3. Line graphing

<http://www.mste.uiuc.edu/courses/ci330ms/youtsey/lineinfo.html>

4. Correlation

Using Excel spreadsheets to find statistical correlation between two sets of data.

- a. Choose a cell where you want to display the results.
- b. Enter an equal sign, then “correl”, and a left parenthesis. ex. =correl(
- c. Describe the range of values for the first variable: ex. =correl (b2:b85
(This describes the series of values for the first variable in column b from cell number 2 to cell number 85.)
- d. Next type a comma (,) and then the range for the second value P
ex. = correl (b2:b 85,d2:d85)

In this example, you are looking for the correlation between the values for first variable listed in column b, rows 2 through 85 and the values for the second variable listed in column d, rows 2 through 85. When you complete entering the formula, hit return and the numerical value for the correlation should appear.