BIG DATA

SMALL DEVICES

INVESTIGATING THE NATURAL WORLD USING REAL-TIME DATA

Donna Governor
Michael Bowen
Eric Brunsell

NSTApress
National Science Teachers Association

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Arlington, Virginia

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Contents

PART 1: USING REAL-TIME DATA IN THE CLASSROOM

PAGE 3

PART 2: SAMPLE ACTIVITIES USING REAL-TIME DATA

PAGE 65

5 INVESTIGATIONS USING REAL-TIME ATMOSPHERE DATA

71

6 INVESTIGATIONS USING REAL-TIME BIOSPHERE DATA

111

7 INVESTIGATIONS USING REAL-TIME GEOSPHERE DATA

141

8 INVESTIGATIONS USING REAL-TIME HYDROSPHERE DATA

171

9

INVESTIGATIONS USING REAL-TIME CELESTIAL SPHERE DATA

201

PART 3: GOING FURTHER

PAGE 229

10

BEYOND THE DATA

231

11

REAL-TIME CITIZEN SCIENCE

239

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Michael Bowen holds a doctorate from the University of Victoria in Canada. After studying the research practices of field biologists, he developed curricula for middle school students that were tested with sixth- and seventh-grade students in the classroom and outdoors. Following a postdoctoral fellowship in the sociology department at Trent University in Ontario, he became a member of the faculties of education at three Canadian universities: Lakehead University, the University of New Brunswick, and Mount Saint Vincent University (where he is now an associate professor). His research has been presented at national and international conferences in Canada, Europe, and the United States. Michael has served as a district director for NSTA and has co-authored two other books for NSTA Press and numerous articles for its journals.

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PREFACE

In the HBO (Home Box Office) series *From the Earth to the Moon*, there is a dramatization of the field geology training that was provided to the Apollo astronauts assigned to the final three missions. Geologist Lee Silver (played by David Clennon) offered an analogy about "context." He said, "If you brought me a dead cat, I can tell you two things about it: It was a cat, and it is dead. If you told me you found it in the middle of the road … what killed the cat? What if you found it in the kitchen of your favorite restaurant?" He was referring to context as the difference between road kill and a meal.

And what does access to large data sets provide to students? It provides a number of supports for learning—most importantly, context. As has been frequently cited in science education reform documents, science learning has often been approached in a manner that has been very broad at the expense of depth. Coverage, it seems, can be the enemy of understanding (Gardner 1991). Context can provide the necessary depth for understanding by making explicit the connections between the science content that we wish for students to learn and the real world. The real world is complex and defies simple understandings—or rather, simple understandings are inadequate for grasping the complex, multivariate patterns that are inherent to the natural world.

This volume embraces the fact that the natural world is complex and multivariate, but through the three-dimensional learning structure of *A Framework for K–12 Science Education* (*Framework;* NRC 2012), this complexity is not necessarily complicated. Complex systems operate on a variety of scales and evolve over time with the amount of energy present in the system (Fichter, Pyle, and Whitmeyer 2010). Understanding systems, a fundamental part of the crosscutting concepts, does not mean that a deterministic outcome is available. Rather, recognizable patterns can be displayed by comparing data related to natural Earth phenomena, whether they are the mapped distribution of earthquake epicenters or the variations in temperature and humidity with altitude across locations. The more data that are available, the more robust are the inferences that can be made regarding complex relationships, and the clearer is the pattern that can emerge. By analyzing changes in the patterns, other crosscutting concepts can be accessed, such as stability and change; cause and effect: mechanism and explanation; and scale, proportion, and quantity.

The other critical aspect of the *Framework* that goes beyond the disciplinary core ideas is the practices employed by scientists and engineers as they go about their work. This volume is well-positioned to use the science and engineering practices to provide context as well. As was illustrated in the now infamous "climategate" email hacking incident (Cook 2016), the public has a different understanding of "data manipulation" than scientists employ. To properly analyze and interpret data, particularly large data sets, scientists have to organize the data in a manner that makes sense for generating and testing models, as well as for generating arguments from these data. A connective practice is the use of mathematical and computational thinking, which not only provides context to scientific thinking, but also provides a platform for teachers of mathematics and science to reconcile language and terminology differences that cause students to have endless frustration.

Context for large data sets thus is critical not only to scientific understanding, but also to learning how to understand the natural world from a scientific standpoint. Fundamentally woven in the performance expectations within the *Next Generation Science Standards* (*NGSS;* NGSS Lead States 2013), context is the basis by which we can distinguish ourselves from the automated devices we use to collect such data and evaluate whether or not the data are accurate, valuable, and sufficient. I trust you will find this volume useful not just in teaching science, but also in using science as a way to grasp the complexity of the natural world with awe and wonder, instead of fear.

Eric J. Pyle, PhD
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Coordinator, Science Teacher Preparation, College of Science and Mathematics
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Gardner, H. 1991. *The unschooled mind: How children think and how schools should teach*. New York: Basic Books.

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NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards*.

6

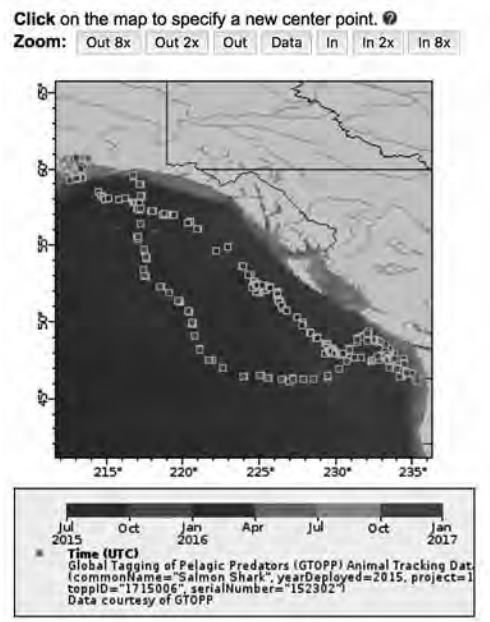
INVESTIGATIONS USING REAL-TIME BIOSPHERE DATA

The biosphere is the part of Earth that is composed of living organisms. This includes humans, ducks, grass, trees, snails, algae … well, you get it. Data on animals, insects, and other life forms are often collected by researchers studying their behavior. Environmental scientists study the environment and how organisms interact with it. Information about people is often collected by governments and population researchers. Data can be collected using digital instruments, cameras, surveys, and even simply by observation.

Human populations—a topic in every environmental science course—can be explored in great detail at the U.S. Census Bureau website (*www.census.gov/topics/population.html*). Interactive maps are one way that population trends can be explored with real-time data. The *NASA Earth Observations* (*NEO*) website (*http://neo.sci.gsfc.nasa.gov*) provides real-time data for several Earth systems. The data sets in the site's "Life" category are graphic models—monthly maps that provide information about net primary productivity, leaf area, chlorophyll concentration, and several other research topics. The National Oceanic and Atmospheric Administration (NOAA) *Integrated Ocean Observing System Animal Telemetry Network* (*IOOS ATN*) website (*http://oceanview.pfeg.noaa.gov/ATN*) allows tracking of marine animals. Web cameras at zoos, nature conservatories, and other locations can provide a way for students to do population studies or watch interactions between organisms and their ecosystems. There are osprey cams, bee cams, fall-foliage cams, and even naked mole rat cams. These provide a rich source of data that help students to better understand how specific species function in their environment.

One useful investigation through which to explore how life interacts with the environment would be to correlate current sea-surface temperature to past and present movement of marine animals using the *IOOS ATN* website. Figure 6.1 (p. 112) contains screenshots of site content showing the movement of a tagged salmon shark over a six-month period in 2015. On the site, students can watch the movement of specific marine animals over a number of days or compare the most recent location of different species. Students also can use site information to infer the preferred conditions of different species and compare their inferences to information learned through environmental studies research.

Figure 6.1. Sample of data available on the NOAA *Animal Telemetry Network* website



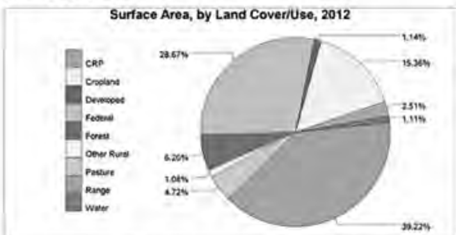
Source: http://oceanview.pfeg.noaa.gov/ATN.

Land use is a topic studied in every environmental science course. The U.S. Department of Agriculture (USDA) website (*www.nrcs.usda.gov*) provides data on land use and soil resources. A possible investigation using the *USDA* data would be to compare and contrast land-use trends for different states. For example, Figure 6.2 shows the latest data for land use for Montana and New Jersey. These two states are very different in many ways, including geography and population density. New Jersey has a population density of 1,210 people per square mile, whereas Montana's population density is seven people per square mile. You could ask students to investigate how land use in these states has changed over time, and to develop an explanation about why there are so many differences in land use in these states. How do weather and climate affect each's use of land? What other variables contribute to the differences shown?

Again, the investigations that follow are only a few of the many ideas that you could use to explore the biosphere. Use these as a starting point … and see what new ideas you generate with the real-time resources that are available. Tables 6.1 and 6.2 (pp. 138 and 139, respectively), list all digital resources used in this chapter.

Figure 6.2. Land-use comparison charts for Montana and New Jersey

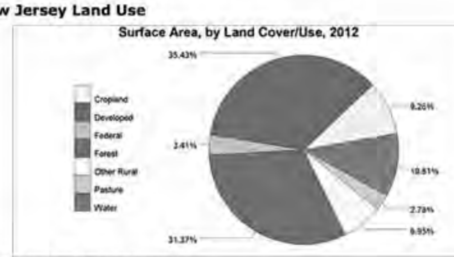
Montana Land Use



Total Surface Area, by Land Cover/Use
In thousands of acres, with margins of error

Land Cover/Use		1982	1987	1992	1997	2002	2007	2012
Federal land		26,865.1 —	26,775.4 —	26,681.8 —	26,756.5 —	26,779.9 —	26,843.3 —	26,983.6 --
Water areas		1,054.6 —	1,053.3 —	1,044.2 —	1,033.2 —	1,035.5 —	1,038.4 —	1,042.9 --
Non-Federal Land	Developed	829.6 ± 92.1	840.3 ± 91.9	892.6 ± 97.9	953.6 ± 102.6	990.4 ± 106.6	1,045.9 ± 116.0	1,069.8 ± 120.1
	Rural	65,360.7 ± 105.0	65,441.0 ± 105.3	65,491.4 ± 113.4	65,366.7 ± 116.4	65,304.2 ± 117.4	65,182.4 ± 126.5	65,013.7 ± 130.6
	Total	66,190.3 ± 51.5	66,281.3 ± 51.5	66,384.0 ± 48.4	66,320.3 ± 44.8	66,294.6 ± 33.5	66,228.3 ± 33.1	66,083.5 ± 32.9
Total surface area		94,110.0 —	94,110.0 —	94,110.0 —	94,110.0 —	94,110.0 —	94,110.0 —	94,110.0 —

New Jersey Land Use



Total Surface Area, by Land Cover/Use
In thousands of acres, with margins of error

Land Cover/Use		1982	1987	1992	1997	2002	2007	2012
Federal land		156.3 —	159.1 —	169.4 —	169.4 —	175.0 —	176.7 —	177.6 —
Water areas		553.7 —	555.5 —	558.7 —	562.0 —	562.9 —	563.5 —	563.6 —
Non-Federal Land	Developed	1,177.4 ± 68.0	1,385.1 ± 72.8	1,454.2 ± 71.4	1,652.5 ± 75.2	1,771.5 ± 78.6	1,824.6 ± 80.0	1,848.0 ± 79.9
	Rural	3,328.2 ± 71.4	3,115.9 ± 72.3	3,033.3 ± 75.5	2,831.7 ± 78.3	2,706.2 ± 81.9	2,650.8 ± 83.3	2,626.4 ± 83.6
	Total	4,505.6 ± 9.4	4,501.0 ± 9.2	4,487.5 ± 9.4	4,484.2 ± 8.5	4,477.7 ± 8.4	4,475.4 ± 8.7	4,474.4 ± 9.3
Total surface area		5,215.6 —	5,215.6 —	5,215.6 —	5,215.6 —	5,215.6 —	5,215.6 —	5,215.6 —

Source: Natural Resources Conservation Service. *www.nrcs.usda.gov/wps/portal/nrcs/rca/national/technical/nra/rca/ida.*

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Annenberg LLC. 2016. Explore. *http://explore.org*.

Natural Resources Conservation Service. *www.nrcs.usda.gov/wps/portal/nrcs/rca/national/technical/nra/rca/ida*.

TEACHER NOTES: WILDFIRE!

<table>
<tr><td>Learning Goal</td><td colspan="2">Students will determine whether there is a correlation between drought and wildfires using data from two states.</td></tr>
<tr><td>Disciplinary Core Ideas</td><td colspan="2">• The roles of water in Earth’s surface processes
• Natural hazards</td></tr>
<tr><td>Science and Engineering Practices</td><td colspan="2">• Analyzing and interpreting data
• Constructing explanations and designing solutions</td></tr>
<tr><td>Crosscutting Concepts</td><td colspan="2">• Cause and effect: Mechanism and explanation
• Stability and change</td></tr>
<tr><td>Background Information</td><td colspan="2">Usually about 100,000 wildfires are reported each year in the United States. Although drought and wildfires are separate hazards, they are related. Weather conditions such as drought can contribute to wildfires, which can begin in dry, hot conditions. As climates change, areas that become hotter can have increased rates of evaporation, leading to drier conditions.</td></tr>
<tr><td colspan="3">DATA AND TECHNOLOGY</td></tr>
<tr><td>Online Sources</td><td>• National Drought Monitor, National Drought Mitigation Center website: http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx
• National Interagency Fire Center website: www.nifc.gov/fireInfo/fireInfo_statistics.html
• QR Codes: See Table 6.1 (p. 138).</td><td rowspan="2">National Drought Monitor website screenshot


Source: http://droughtmonitor.unl.edu.</td></tr>
<tr><td>App and Device Sources</td><td>No appropriate apps were located for this activity for either data set.</td></tr>
<tr><td>Technology Notes</td><td colspan="2">• Students must access the data using the websites. Neither website has a responsive design; however, on both websites, the data are easily accessed and can be gathered using personal devices.
• National Drought Monitor, National Drought Mitigation Center website: The link provided opens the site’s Tabular Data Archive. From the left-side drop down menu, select “State” (defaults to “National”). The data are sortable by drought severity.
• National Interagency Fire Center website: In the “Statistics” column, under “Historical year-end fire statistics by state,” select the data year by year.</td></tr>
</table>

DATA AND TECHNOLOGY (*continued*)	
About the Data	**Data Sampling:** This activity requires students to sample drought data from a complex data set. The highest percentage of area experiencing extreme drought is to be considered the sample data point for each year. Instead of selecting the acreage of wildfires, students could instead work with the number of wildfires. **Data Type:** The drought and wildfire data both are interval–ratio (measured) types of data. **Data Issues:** The National Interagency Fire Center website data are annual, whereas the *National Drought Monitor* data are weekly, creating a mismatch between values. Calculating mean (average) and median values for each year would require an extra step but using those values might be more appropriate, because drought conditions vary across months within the same year. Note that the *x-y* graph will have two states on it, and a line of best fit will be required for each state, so students should use a different symbol (for example, * and +) for each data set.
USING AND ADAPTING THE ACTIVITY	
About the Activity	Students should have a basic understanding of drought conditions and understand the difference between a prescribed burn and a wildfire. The drought data will be more difficult for students to work with because they are broken down by week, whereas the wildfire data are supplied by state. Students will make generalizations from drought data by sorting through the weekly data to find the highest percentage of extreme drought severity for each year.
Scaling Down	To simplify this activity, reduce the amount of data collected by having students work only with data from the single highest and lowest drought years, rather than across the entire data span and data compared using simpler graphs, such as a bar graphs. Model the activity by collecting the data from your home state as a class, and then have students research additional states in teams, with one student collecting the wildfire data and the other drought data.
Scaling Up	For added complexity, students can collect drought data by category (abnormally dry, moderate drought, severe drought, extreme drought, exceptional drought) and can compare different types of statistics, such as population affected rather than area in drought. In addition, data can be presented annually as a double line graph of data over time.

USING AND ADAPTING THE ACTIVITY *(continued)*	
Extending	**Does El Niño Play a Part?:** Have students research to see whether El Niño Southern Oscillation patterns (El Niño, La Niña) affect drought conditions in their area. **Climate Connections:** Students can research annual temperature and precipitation data in their states to determine the relationship between weather and wildfires. **Wildfire Safety:** Have students download the *American Red Cross Wildfire* app, research current wildfires, and then create a wildfire safety brochure. **Enrichment Using Data:** To classify the drought before comparing it to wildfire data, students can develop a drought-severity index for each year that takes into account the number of weeks of drought, the severity of the drought, and the highest level reached over the course of the year.

ASSESSMENT NOTES
In general, expect to see a positive correlation between drought and wildfires; however, this might not always be the case because often other factors are involved as well.

Name: ___________________________

STUDENT HANDOUT: WILDFIRE!

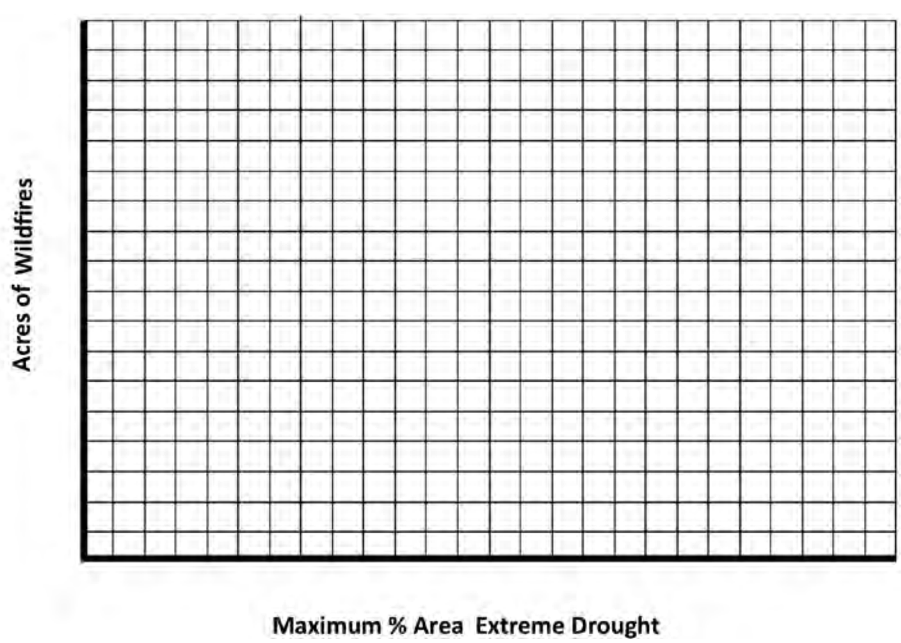
Activity Goal	In this activity, you will explore the relationship between drought and wildfires.
Technology Notes	You will access data from two websites: 1. *National Drought Monitor,* National Drought Mitigation Center: *http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx* 2. National Interagency Fire Center: *www.nifc.gov/fireInfo/fireInfo_statistics.html*
Orientation Questions	• How do droughts affect ecosystems? • What conditions lead to an increase in the number of wildfires?
Directions	1. For this activity you will be research information from two states, as assigned by your teacher. One state may be your own. You will collect data for the most recent 12 years or for another range defined by your teacher. 2. *National Drought Monitor* website: Find the percent area in the “extreme drought” category for your state(s). From the left-side drop-down menu, select “State” (rather than “National”) and then, from the middle drop-down menu, choose the state you are researching. Because the data are shown by week, you will search by year and then sort on the “Extreme Drought” column (red) to find the maximum percent area of extreme drought for that year. Enter those data into the data table. 3. National Interagency Fire Center website: In the “Statistics” column, under “Historical year-end fire statistics by state,” find the data for the number of acres of wildland fires for your state for each year. Enter the data in the data table. 4. Complete the Data Analysis, Analysis Questions, Conclusions, and Reflection Question sections.

Data Table

State:			State:		
Year	Maximum Area of Extreme Drought (%)	Wildland Fire Area (Acre)	Year	Maximum Area of Extreme Drought (%)	Wildland Fire Area (Acre)

Data Analysis

Construct a scatter plot to determine whether there is a correlation between drought conditions and the number of wildland fires for your two states. Use a different symbol for each state's data.



Analysis Questions

1. In what year was the drought the greatest in each state? How many acres were lost to wildfires in each of those years?

2. In what year was the drought the least in each state? How many acres were lost to wildfires in each of those years?

3. Why was drought used as an indicator of climate conditions in this activity?

4. Besides drought, what other variables could affect the number of wildfires?

5. Would you expect the impact of drought to be the same for different biomes (for example, desert, woodland)? Why or why not?

Conclusions

Construct an explanation that describes why wildfires might be more likely to occur during or after drought years. Use evidence you collected, if applicable, to support your conclusion.

Reflection Question

With climates changing, some places are becoming hotter and drier. How might state officials change their preparedness for wildfires for states that are experiencing more droughts?

Table 6.1. Data sources for real-time biosphere investigations

Activity	Website	URL	QR Code
Behavior Ethograms	Explore	*http://explore.org*	
Emerging or Developed?	CIA *World Factbook*	*https://cia.gov/library/publications/resources/the-world-factbook*	
This Land Is Our Land	2007 USDA Major Land Uses Report	*www.ers.usda.gov/data-products/major-land-uses*	
	U.S. Census Bureau *Historical Data*	*www.census.gov/popest/data/historical/index.html*	
	USDA *Resources Soil and Water Conservation Act (RCA) Interactive Viewer*	*www.nrcs.usda.gov/wps/portal/nrcs/rca/national/technical/nra/rca/ida*	
Wildfire!	*National Drought Monitor,* National Drought Mitigation Center	*http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx*	
	National Interagency Fire Center	*www.nifc.gov/fireInfo/fireInfo_statistics.html*	

Table 6.2. Additional biosphere-related data sources

Website	Address	QR Code
USDA *National Agriculture Statistics Service*	*www.nass.usda.gov/Charts_and_Maps/Crops_County*	
NOAA *Integrated Ocean Observing System Animal Telemetry Network*	*http://oceanview.pfeg.noaa.gov/ATN*	
Vegetation Condition Explorer	*https://nassgeodata.gmu.edu/VegScape*	

INDEX

Page numbers in **boldface** type refer to tables or figures.

D

BIG DATA SMALL DEVICES

INVESTIGATING THE NATURAL WORLD USING REAL-TIME DATA

"As a classroom teacher with a background in instructional technology, I found smartphones and tablets to be the perfect devices for having students access real-time data for classroom investigations. I began using these in my own room, then started sharing ideas at teacher conferences. What I immediately found is that there is a great deal of interest in using personal technology devices as learning tools."

—Donna Governor, co-author of *Big Data, Small Devices*

Given the number of students with smartphones and tablets, it only makes sense for them to take advantage of the many websites and free apps that can teach them about the natural world. *Big Data, Small Devices* is designed for Earth and environmental science teachers who want to help students tap into, organize, and deploy real-time data sets. Students can learn to use their devices to detect patterns among phenomena related to the atmosphere, biosphere, geosphere, hydrosphere, and celestial sphere.

Written by veteran teachers, *Big Data, Small Devices* will help you understand both the technology you need and the ways to use it in classes at all levels, from elementary school through high school. The authors give tools, tips, and tricks for finding real-time data and using them to create your own investigations. Then, they provide sample activities that showcase specific data, as well as the websites and apps that provide them. You can use the activities as written, adapt them to your specific needs, or use them as inspiration for creating your own.

Big Data, Small Devices is a one-of-a-kind book for developing investigations with any data accessible online. It also helps you bring learning opportunities for your students as close to them as their personal technology devices.

Grades 3–12

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