

Technology-Based Inquiry for Middle School

An NSTA Press Journals Collection

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Edwin P. Christmann, Editor

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Contents

Section I: Scientific Inquiry

What is inquiry?	1
What does the NSES say about scientific inquiry?	3
Literature review	6

Section II: Physical Science

Chapter 1: Time for Class	9
<i>Edwin P. Christmann</i> (September 2004)	
Chapter 2: Converting With Confidence	11
<i>Edwin P. Christmann</i> (May 2000)	
Chapter 3: A Different Phase Change.....	15
<i>Lyndsay B. Link and Edwin P. Christmann</i> (November/December 2004)	
Chapter 4: Temperature Tracking	19
<i>Jeffrey Lehman and Edwin P. Christmann</i> (September 1997)	
Chapter 5: Probing for Answers.....	23
<i>Edwin P. Christmann</i> (January 2004)	

Section III: Earth and Space Science

Chapter 6: Who Solved the Longitude Problem?.....	27
<i>Edwin P. Christmann</i> (September 2002)	
Chapter 7: Celestial Observation Tools.....	31
<i>Edwin P. Christmann</i> (October 2002)	
Chapter 8: Ready to Navigate: Classroom GPS Applications.....	35
<i>Robert A. Lucking and Edwin P. Christmann</i> (November/December 2002)	
Chapter 9: Layers of Information: Geographic Information Systems (GIS)	41
<i>Robert A. Lucking and Edwin P. Christmann</i> (January 2003)	

Chapter 10: Underwater Web Work.....	47
<i>Mervyn J. Wighting, Robert A. Lucking, and Edwin P. Christmann (May 2004)</i>	
Chapter 11: Up-to-the-Minute Meteorology.....	51
<i>Mervyn J. Wighting, Robert A. Lucking, and Edwin P. Christmann (February 2004)</i>	
Chapter 12: Technology-Based Planetary Exploration.....	55
<i>John Harrell, Edwin P. Christmann, and Jeffrey Lehman (January 2002)</i>	
Chapter 13: How Reliable Is the Temperature Forecast?.....	59
<i>Edwin P. Christmann (April/May 2005)</i>	
Chapter 14: Viewing Volcanoes.....	63
<i>Mervyn J. Wighting, Robert A. Lucking, and Edwin P. Christmann (March 2005)</i>	
Chapter 15: In Flight, Online.....	67
<i>Robert A. Lucking, Mervyn J. Wighting, and Edwin P. Christmann (February 2005)</i>	
Section IV: Life Sciences	
Chapter 16: Data Collection and Analysis Tools.....	71
<i>Edwin P. Christmann (November/December 2003)</i>	
Chapter 17: The Latest in Handheld Microscopes.....	75
<i>Mervyn J. Wighting, Robert A. Lucking and Edwin P. Christmann (March 2004)</i>	
Chapter 18: Aqua Analysis.....	81
<i>Justin Sickles, Edwin P. Christmann, and Jeffrey Lehman (May 2001)</i>	
Chapter 19: Fast-Food Fact Finding.....	85
<i>Edwin P. Christmann, Jill Konton, and Jeffrey Lehman (February 1999)</i>	
Chapter 20: Testing the pH of Soft Drinks.....	89
<i>Edwin P. Christmann and Adam J. Holy (July 2005)</i>	
Section V: General Science and Technology Applications	
Chapter 21: Graphing Calculators.....	93
<i>Edwin P. Christmann (February 2002)</i>	
Chapter 22: Personal Digital Assistants (PDAs).....	97
<i>Edwin P. Christmann (April 2002)</i>	

Chapter 23: Projecting Your PDA	101
<i>Edwin P. Christmann</i> (May 2003)	
Chapter 24: Science Research on the Internet	105
<i>Robert A. Lucking and Edwin P. Christmann</i> (February 2003)	
Chapter 25: Technologies for Special Needs Students	111
<i>Edwin P. Christmann and Roxanne R. Christmann</i> (March 2003)	
Chapter 26: Software That Makes the Grade	117
<i>Edwin P. Christmann</i> (July/August 2004)	
Chapter 27: Computer-Assisted Instruction	121
<i>Edwin P. Christmann</i> (May 2002)	
Appendix: About the Authors	125
Index	127

Additional Materials Available Online

Technology constantly evolves as new discoveries are made and new uses are found. To supplement the chapters in this book, I've created a web page with additional information on each chapter. There you'll find up-to-date information, including chapter reviews, outlines, sample test questions, and activities. You can download PowerPoint presentations for teaching the text as well.

Please visit <http://srufaculty.sru.edu/edwin.christmann/epc2.htm>.

Scientific Inquiry

“The aim of natural science is not simply to accept the statements of others, but to investigate the causes that are at work in nature.”

—Albertus Magnus

EDWIN P. CHRISTMANN

A brief history

In 1972 Karl Popper traced the beginnings of the scientific method to the turn of the sixth and fifth centuries B.C., in ancient Greece. During this time the Greeks tried to understand or explain the structure of the Universe in terms of the story of its origin. It was not until the 13th century, however, that Albert the Great (i.e., Albertus Magnus, circa 1197 to 1280 AD), the prolific Dominican Friar and professor, wrote 36 volumes on what was then known as “natural philosophy.” Subsequently he is known as the father of the natural sciences, which are now divided into physics, geology, astronomy, chemistry, and biology.

During the medieval era, science was not the process of inquiry that it is today. Therefore, as an early scientist, Albert the Great relied on his encyclopedic scientific knowledge, which he synthesized from Aristotle’s Greek texts and the Arab writings. It is with Albert the Great that the earliest scientific experiments are documented with students in his laboratory at the University of Cologne. As an experimenter, Albert the Great built up a collection of plants, insects, and chemical compounds, laying the groundwork for later scientific inquiry in his laboratory. Kovich

and Shahan (1980) verify that during Galileo’s professorate at the University of Pisa, his notebooks mention Albert the Great 23 times in his logical and physical questions. Clearly, it is around this era during the 15th century, in the time of Galileo, when science transforms into a process of inquiry.

Subsequently, technological advances led to the development of experimental tools, an advancement that catapulted scientific knowledge into an ongoing process of scientific investigation. No longer did an alchemist work as a mere craftsman in that the modern era of science is a field harnessed by technology, steered by the scientific method, and fueled by the process of scientific inquiry. Undoubtedly, the applications of the latest technologies (e.g., microcomputers, internet, and calculators) have increased the rate at which scientific problems are investigated and solved. There is little doubt that these technological advances have improved the quality of life for the majority of people throughout the world. Thus, students should be familiar with the latest technologies that are used in the process of scientific inquiry, as well as have rich experiences in science classrooms in middle schools throughout the United States.

Section I

Scientific Inquiry

What is science?

Trefil and Hazen (2004) explain that, based on experiments and observation, science is a way of knowing that answers questions about the natural world that surrounds us. Subsequently, science is based on verifiable facts about physical phenomena. According to the tenets of the National Science Education Standards (1996), students should be guided by the following principles when studying science:

- Science is for all students.
- Learning science is an active process.
- School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.
- Improving science education is part of systematic education reform.

Science is everywhere around us. Science is involved with the water that we drink, the food that we cook, the bicycles that we ride, and the stars in the night sky. Most important, however, is that science is fun. The activities in this book integrate some of the latest technologies into classroom activities, which will hopefully provide students with some of the excitement that scientists have experienced through the joy of conducting their own scientific experiments. Most important, however, is that students gain an understanding of some of the key terminology that is used by scientists. Below are some very important concepts that are prerequisite to an in-depth understanding of scientific inquiry.

Scientific hypotheses

Based on observations, science is a collection of knowledge about nature of the physical world. Hence, scientists make hypotheses (educated guesses) in attempts to explain observations by testing hypotheses through experiments. Therefore, scientific questions can be tested and verified through experiments, resulting in new knowledge that can be built upon by future generations.

Scientific theories

Scientific theories are tentative detailed explanations and descriptions of the world that cover a relatively large number of phenomena. Theories offer the scientific community testable observations that are predictable and useful for further investigation. Some examples of scientific theories are relativity, evolution, and plate tectonics. It is important to emphasize, however, that theories are unconfirmed and may be modified or even discarded with new scientific findings. Hence, scientific theories help to expand the body of scientific knowledge, which is constantly developing, changing, and contrary to popular opinion, is never absolute.

Scientific laws

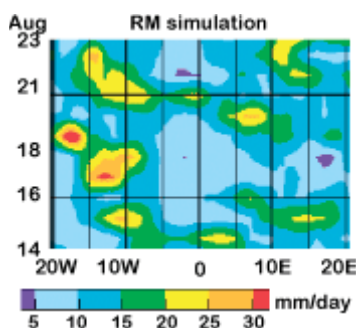
Scientific laws are based on large amounts of scientific data and can be summarized by a brief statement. For example, Newton's First Law of Motion states, "Every object either remains at rest or in continuous motion with constant speed unless acted upon by external forces." A scientific law is subjected to rigorous testing by a variety of experiments that are replicated several times. A valid scientific law can predict natural phenomena with great precision. For example, Newton's Second Law of Motion states, "The rate of change of momentum of a moving body is proportional to and in the same direction as the force acting on it." For example, if you kick a football, its path through the air is not a straight line; due to gravity the football curves toward the Earth. Many times laws are expressed mathematically. For example Newton's Second Law of Motion can be expressed algebraically as $F = ma$.

Scientific models

A scientific model can be used to help explain phenomena by revealing ideas about a complicated system from a simple system. For example, Figure 1 is a NASA Rainfall Model that forecasts weather observations with a computer-based

Figure
1

NASA Rainfall Model



Daily regional model rainfall forecasts for the region between 20°W-20°E (averaged over 5-15°N) during Aug. 14-23, 2002.

Taken from http://www.giss.nasa.gov/research/briefs/druyan_06/

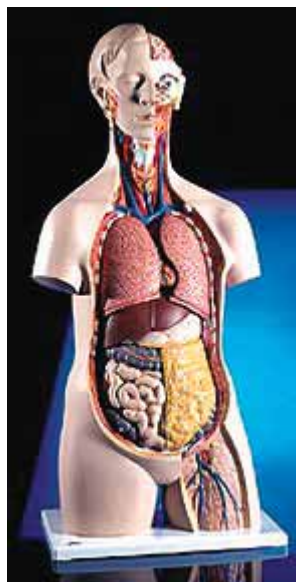
model. The computer-based model uses predictions based on past observations to fill in the data sets. Some other examples of scientific models are mixing baking soda and vinegar to simulate volcano eruptions, using marbles to represent gases, and examining a model of a human torso (see Figure 2). Subsequently, scientific models can give visual representations to represent something that cannot readily be seen.

Scientific inquiry

The National Research Council (1996) emphasizes “scientific inquiry” as a way for students to be engaged with conceptualized questions that seek explanations of the world surrounding them. In essence, learning through scientific inquiry gives students an opportunity to investigate problems methodologically; similar to the procedures used by scientists. To simplify the process of scientific inquiry, Figure 3 shows how an observation of a natural phenomenon is questioned and tested through a sequential process. Based on a hypoth-

Figure
2

Human Torso Model



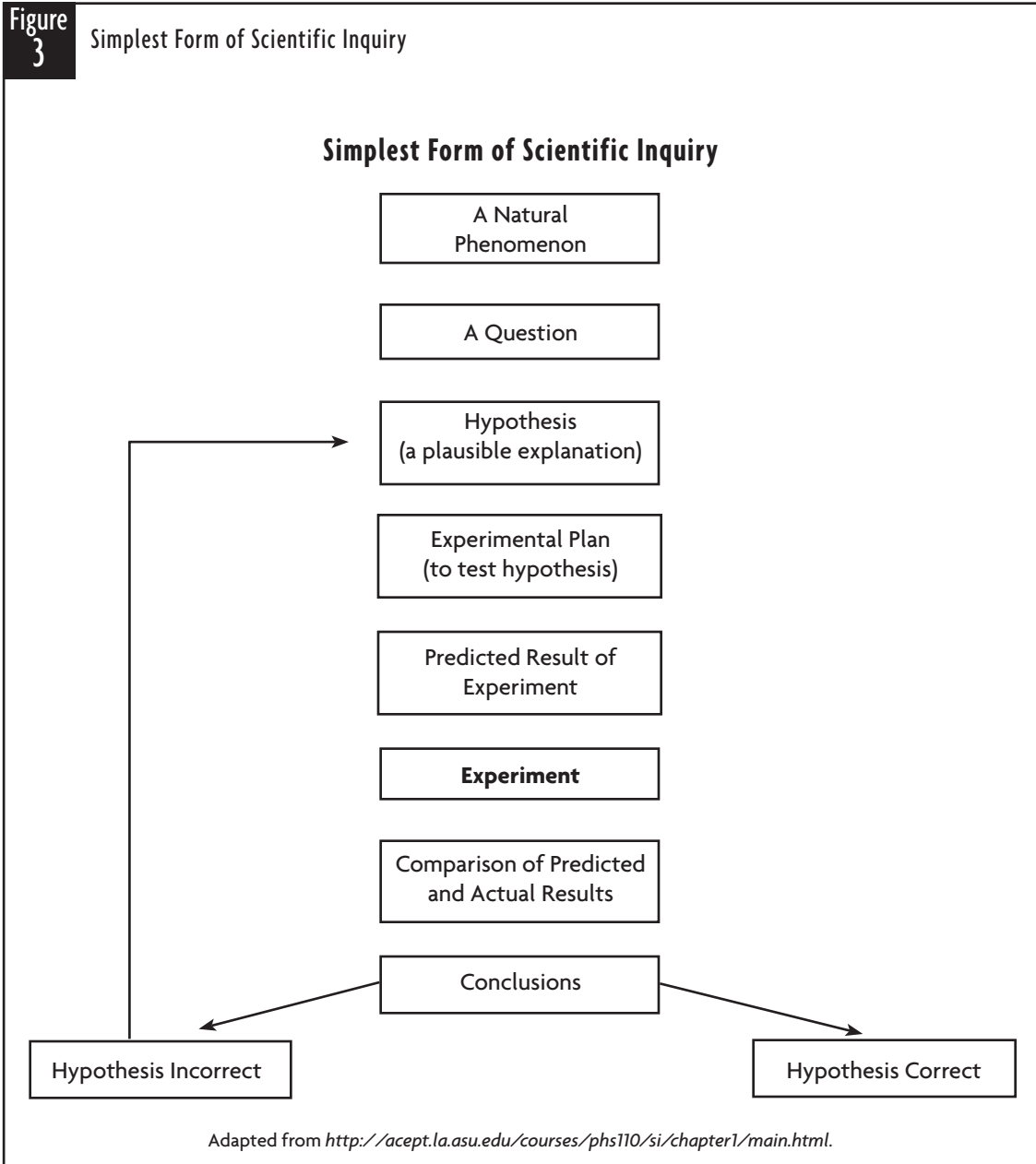
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esis (a plausible explanation), an experiment is conducted, which culminates into a conclusion that is based on whether or not the hypothesis is rejected.

Again, it is important to emphasize that scientific inquiry is an ongoing process that can result in replicated experiments so that the scientific community have valid and reliable findings. As discussed earlier, this process of replication draws on previous experiments and uses known scientific theories, laws, and models. Therefore, as presented in Figure 4, scientific inquiry is a cyclical process that, based on a natural phenomenon, begins with a question. For example, if we are interested in the air temperature at a specific location, we can set up an experiment to take temperature readings. Subsequently, by recording hourly temperature readings at the same location, we can compare readings taken in September to

Section I

Scientific Inquiry

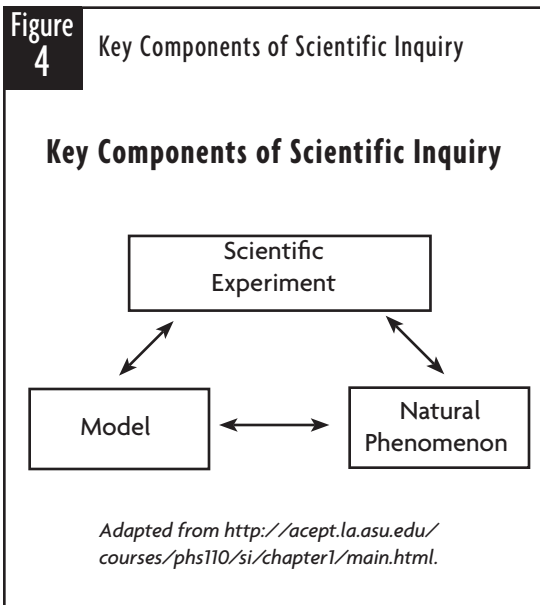


those taken in January and examine the variation between the results. Once the results have been gathered, a computer spreadsheet model with graphics can be used to show differences in factors that have caused temperature differences (e.g., direct sunlight time). Thus, models can be used to present additional experiments. Clearly, scientific

inquiry is essential for the middle school science student in that this process makes connections with prior scientific knowledge.

The middle school science student

Most middle school science teachers are aware that students in grades 6 through 8 are developing



abstract and logical thinking skills. Jean Piaget, the famous developmental psychologist, explained that middle school age children are moving through a developmental period where they are able to generate abstract propositions and multiple hypotheses. At this stage, which is known as Formal Operations, thinking becomes less tied to concrete reality and more reliant on rational judgments. Simultaneously, the world surrounding them is changing in a seemingly random, yet predictable, pattern. For example, children now are observing objects moving through the sky, and noticing, for example, that the Earth's materials have different physical and chemical properties. Perhaps more obvious to middle school students, however, are the changes that surround them from day to day and over the seasons. Subsequently, this stage in human maturation is ideal for middle school learners to be engaged in learning activities that are scientific and inquiry-rich.

Technology-based inquiry

The transition from using simple “found tools” to making tools and keeping them for future use is the essence of the intellectual and social evolution of the human species (Devore, 1980).

As discussed earlier, the use of technologies has increased the rate at which scientific problems are solved. For instance, John Harrison, a 19th Century cabinetmaker, solved the problem of longitude by using some of the tools of his era (i.e., mechanical clocks and basic astronomy) to solve one of the most difficult problems of his age. Harrison's technological solution to the problem of longitude was to compare a clock's time at the prime meridian to the time of the unknown position at noon at that unknown point. Subsequently, the time at noon of the unknown position was compared to a mechanical clock (i.e., a chronometer) carried on a ship. Hence, the mechanical clock needed to provide a precise time measurement for the prime meridian as a comparison to the noontime reading at the unknown point. Since time difference is equated to: $[\text{hours}/24 \times 360 = \text{longitude in degrees}]$, knowing the time at noon and the time at the prime meridian can be used to calculate longitude. Today, technological advancements with satellites and computer technologies have made it possible to measure longitude with a handheld global positioning system (GPS). Measurements taken with a GPS can be taken easily with levels of accuracy that would even amaze John Harrison, who dedicated 50 years of his life to find a solution to measure longitude.

Today, middle school science teachers have a unique opportunity to harness some of the same technologies that are available to scientists. For example, a graphing calculator can be linked to a probe (e.g., voltage probes, light sensors, and motion detectors) and data can be collected from laboratory activities and, with great precision, later uploaded to computer software. For life science lessons, a teacher can purchase a video microscope for about \$300.00 and have students digitize still images of specimens. Most accessible, however, is the kaleidoscope of technological applications available for teachers via the internet. For example, using a directory of websites, teachers can connect their classrooms to images from a VolcanoCam focused on the crater of

Section I

Scientific Inquiry

Science as Inquiry Standards

In the vision presented by the Standards, inquiry is a step beyond “science as a process,” in which students learn skills, such as observation, inference, and experimentation. The new vision includes the “processes of science” and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop

- Understanding of scientific concepts.
- An appreciation of “how we know” what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquirers about the natural world.
- The dispositions to use the skills, abilities, and attitudes associated with science.

Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students’ activities. The standards on inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. Table 1 shows the standards for inquiry. The science as inquiry standards are described in terms of activities resulting in student development of certain abilities and in terms of student understanding of inquiry.

Table 1 Science as Inquiry Standards

Levels K–4

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

Levels 5–6

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

Levels 9–12

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

Note: All of the material in this box was taken directly from the NRC Standards.

Science and Technology Standards

The science and technology standards in Table 2 present students with opportunities to develop decision-making abilities about the natural world that surrounds them. The science and technology standards stress that science is linked to technology as an ongoing process. For example, an engineer uses the fundamentals of science as building blocks to create useful products. The emphasis here, however, is that technology can be used as an essential tool for students to engage in the process of scientific inquiry.

**Table
2**

Science and Technology Standards

Levels K–4	Levels 5–8	Levels 9–12
Abilities distinguish between natural objects and objects made by humans	Abilities of technological design	Abilities of technological design
Understanding about science and technology	Understanding about science and technology	Understanding about science technology

Therefore, as suggested in the NRC Standards, technology is “...a complement to the abilities developed in the science as inquiry standards, these standards call for students to develop abilities to identify and state a problem, design a solution—including a cost and risk-and-benefit analysis—implement a solution, and evaluate the solution. Science as inquiry is parallel to technology as design. Both standards emphasize student development of abilities and understanding.”

Mount St. Helens, or to a schematic of a volcanic eruption that looks real and is more interesting to young students than the baking soda and vinegar model that has been used as a simulation in the past by teachers. If teachers are covering a unit on volcanoes, they can show students websites that describe the eruption of Mount Vesuvius in Italy in 79 AD and Krakatoa in the Indonesian arc in 1883. As long as inquiry-based lessons are in compliance with the tenets of the National Science Education Standards, teachers can use technology as a tool for inquiry in the framework outlined in the National Standards.

Conclusion

Technology-based inquiry is a pedagogical approach for middle school science teachers to give students the opportunity to use the latest tools to explore the natural world. Through hands-on experiences with the graphing calculators, calculator-based labs (CBLs), personal digital assistants (PDAs), global positioning systems (GPS), geographical information systems (GIS), and other emerging technologies, science teachers can develop and integrate the skills that can make inquiry-based learning meaningful for

Section I

Scientific Inquiry

students. Hopefully, this book will show you how the tools of today can be implemented for technology-based inquiry in your middle school classroom.

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Probing for Answers

EDWIN P. CHRISTMANN

Recent advances in data-collection technologies have given students access to the same types of probes used by scientists in research labs. Probes allow students to collect data on variables such as pH, acceleration, oxygen, light, and temperature. The devices and accompanying software are very user-friendly, allowing students to easily store, manipulate, and present data as charts, graphs, and tables. They are very similar to those used by scientists working in research laboratories across the United States.

However, before you invest in this technology, you should consider all of your options. Today's data-collection probes are designed to work with three major platforms: desktop and laptop computers, personal digital assistants (PDAs), and graphing calculators. Some probes are device-specific, but others will work across platforms with the use of adaptors.

The software that allows you to manipulate data collected with the probes is also an important consideration, especially if you prefer to export your data to spreadsheet or word processing programs to create lab reports and other documents. Make sure your probe software is compatible with the programs you want to use before you make your purchase.

You must also consider how you will be using the probes. If most of your labs are classroom based, then just about any probe will do. However, if you want to conduct data collection in the

field, you should invest in probes that work with PDAs or graphing calculators.

Of course, the most important consideration for your school will be price. The most cost-effective approach is to buy probes that are compatible with hardware that you already have in your classroom. If you are starting from scratch, the least expensive system would be the graphing calculator/probe combination. The PDA/probe combination would be the next most affordable option, and the computer/probe combo would require the biggest startup investment.

Desktops and laptops

Many probeware packages are available for desktop and laptop systems. The packages vary in price depending on the number and accuracy of the probes, and the type of software included. One example is Pitsco's "Electronic Sensor Kits with Computer Interface" packages, which range in price from \$59 to \$79. Each package includes a complete sensor kit and software package. Another example is Onset Computer Corp's HOBO Data Logger system (see Figure 1). This kit is a bit more expensive at about \$100, but they offer free middle school labs on their website (www.iscienceproject.com/labs/6480_middleschool-labs.html). Onset also reports accuracy levels for all of its sensors. For example, the thermister sensor has an accuracy level of $\pm 0.2^{\circ}\text{C}$. Teachers



Figure 1

Section II

Physical Science

grades K–12 can also borrow a HOBO Data Logger for free to test it out. Visit www.iscienceproject.com/contest/instantloaner.html for details.

Personal digital assistants (PDAs)

Many probeware kits are also available for PDAs. For example, Pasco's Probeware Kit for Palm Handhelds (\$229), includes probes to measure temperature, barometric pressure, humidity, and other variables. The kit also comes with a software package, Data Studio for Palm OS.



Figure 2

Another PDA software system that works very well is the ImagiProbe System (\$249, see Figure 2). An advantage of the ImagiProbe is that it is designed to work with several brands of PDA (such as Palm and Visor). And, as long as your PDA has the proper adaptor, you can use it with probes made by different manufacturers. The ImagiProbe system also comes with a variety of lab activities so teachers can easily incorporate data-collection activities into course instruction.

Graphing calculators

CBL2 (about \$200, Figure 3) from Texas Instruments is a cradle interface system that links a graphing calculator to probes. It is compatible with the TI-73, the graphing calculator recommended for the middle level. It is preprogrammed to work with all Vernier probes. Vernier offers a similar system, LabPro (\$530, Figure 4), that has the added advantage of being able to work with PCs and PDAs. Probes included with this package include a motion



Figure 3



Figure 4

detector, pH sensor, voltage probe, temperature probes, light sensor, exercise heart monitor, force sensor, conductivity probe, gas pressure sensor, and magnetic sensor.

Conclusion

Obviously, for science teachers, the potential for data-collection systems is unlimited. However, if you choose to adopt the latest technologies, the most important consideration should be to select data-collection tools that promote basic understandings of scientific inquiry. It cannot be overemphasized that teachers should make purchasing decisions based on their annual budgets, needs, lab constraints, curriculum requirements, and the compatibility of the data-collection tool with the equipment that is currently in place. Hopefully, the ideas presented here will generate new and innovative ideas concerning the application of data collection tools in middle school science teaching and learning. After all, having your students probing for answers is what scientific inquiry is all about.

National Standards

The use of data-collection tools in the science classroom provides teachers and students with a unique opportunity to conduct inquiry-based activities that teach to the specifications of the NRC's (2000) report on scientific inquiry. Clearly, the use of laboratory activities to foster scientific inquiry with contemporary data-collection tools is an excellent way for science teachers to embrace the inquiry abilities that are proposed in the Content Standard for Science as Inquiry: Grades 5–8, which states:

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence and explanations.

- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.

Online resources

Vernier:

www.vernier.com

Pitsco:

www.pitsco.com

Pasco:

www.pasco.com

HOBO Data Loggers:

www.iscienceproject.com

Texas Instruments:

<http://education.ti.com/us/product/main.html>

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National Research Council (NRC). 2000. *Inquiry and the national science education standards*. Washington, DC: National Academy Press.

Index

A

About Temperatures (website), 20
A&E Classroom (website), 27, 28–29, **28f**
Aeronautics Internet Textbook (NASA), 68
Aeronautics Sign Language Dictionary, The, 68
Albert the Great, 1
A-Lex Instant Lookup English Dictionary, **100f**
alternative keyboards, **114f**
alternative mouse devices, **114f**
American Fact-Finder (U.S. Census Bureau website), 44
American Heart Association, 85
American Meteorological Society, 47
American Red Cross, 51
Anderson, David, 68
ArcData online, **43f**
ArcData Publishing Program, 43
ArcPad, **45f**
ArcView, 42
ArcVoyager, 42
Ask Jeeves for Kids, 106, **107f**
assistive technologies, 112, **114f**
astronomy
 celestial observation tools, 31–34
 PDA software for, 31, **99f**
Atlas, 38–39
atomic clock, 9
Audet, R., 42
Augustine, Saint, 9

B

Badgett, J. L., 11, 121, 122
biology, GIS and, 41
Birch Aquarium, 47, 48

box-and-whisker plots, 20, **20f**, **73f**, **94f**
Bridge website, 47

C

CAI (computer-assisted instruction), 121–123
 for special needs students, 111–112
California Institute of Technology, archives of, 21
career information
 on flight, 68
 on oceanography, 47, 48
CBL2 (Texas Instruments), 24
CDC's Vital and Health Statistics, 95
CD-ROMs
 on flight, 67–68
 on volcanoes, 64–65
censorware, research and, 106
Christmann, E. P., 11, 121, 122
CiteSeer, 105, **106f**
Class Action Gradebook (CalEd Software), 118, **119f**
Class Builder, **119f**
Class Mate Grading Software (Class Mate Software), 117, **119f**
Columbus, Christopher, 27
Compass, 38
computer-assisted instruction. *See* CAI
computer gradebooks, 117–119
computers and data-collection probes, 23
Content Standard A: Science as Inquiry, 93, 108
Content Standard B, 91
Content Standard C: Life Sciences, 79, 87
Content Standard D: Earth and Space Science, 65
Content Standard D: Earth in the Solar System, 29, 39
Content Standard D: Grades 5–8, 49

Index

- Content Standard D: Structure of the Earth System, 45
- Content Standard E: Science and Technology, 29, 39, 45, 108
- Content Standard F: Earth in the Solar System, 34
- Content Standard for Science as Inquiry: Grades 5–8, 24–25
- Content Standard G: History and Nature of Science, 34
- conversions, 11–13
PDA software for, **99f**
- Convert-It!, 12, **99f**
- Copernic, 106–107
- Copernic Agent Professional, 106, **107f**
- Copernicus, 31
- CplxCalPro (graphing calculator), **99f**
- Cyber Patrol, 106
- Cybersitter, 106
- Cyber Snoop, 106
- Cycle Timetable, **100f**
- D**
- data analysis
sample data, **72f**
sample problems, **72f**
for temperature readings, 62
with TI-73, 93–94
tools for, 71–74
- data collection, 93
for meteorology, 51
technology, 23–25
for temperature readings, 60–62
tools for, 71–74
- data organization, 72–73. *See also* plotting data;
spreadsheets
nutrition data, 85–86
PDAs and, 97
on water analysis, 81–82
- data-retrieval skills, 55
- demonstrations, ProScope and, 75
- Dinosaur Hunter, 112
- Discovery School, 64
- DK Multimedia, 112
- Documents to Go, **103f**
- Drinking Water Research Foundation, 81
- E**
- Earth Quest, 112
- Earth science, GIS and, 41
- ebooks, 98
- education games, 121
- Eisenhower National Clearinghouse, 67
- Electrolytes and Nutrition, **100f**
- EPA (Environmental Protection Agency)
GIS datasets, 44
standards for bottled water purity, 81, 82
- eSembler for Education, **119f**
- ESRI (Environmental Systems Research Institute)
ArcData Publishing Program, 43
and GIS software packages, 42
- experimental tools, development of, 1
- E-Z Grader, **119f**
- F**
- fact finding, on fast-food, 85–87
- facts, scientific, 55
- FDA (Food and Drug Administration)
recommended daily allowances, 85
standards of bottled water purity, 81, 82
- 1st Class GradeBook (1st Class Software), **119f**
- Flash Boom, **99f**
- flight, 67–70
- FoilSim II, 68–69
- Ford, Gerald, 11
- freezing point, 15
- From a Distance: An Introduction to Remote Sensing/GIS/GPS (website), 37
- Fugawi (software), 44
- G**
- Galileo Galilei, 27
telescope of, 31
- gender, CAI and, 11
- General Conference on Weights and Measures
definition of the second, 9
on International System of Units (SI), 11

- geography
 GIS and, 41
 integrated to GPS navigation, 36
 Geography Network, 43
 Gillis, Kathryn, 47, 48
 GIS (Geographic Information Systems), 35, 41–45
 creation of data, 43
 sample layers of information, **42f**
 Global Weather Services, 52
 GoMOOS, 48
 Google Groups, 107, **108f**
 Google Toolbar, 109
 Go! Temp probe, 60
 GPS (Global Positioning System), 35–40
 applications for PDAs, **36f**
 receiver, **36f**
 GradeBooks for Windows (Russ and Ryan Edware), **119f**
 gradebook software, 117–119
 packages, **119f**
 Grade Machine (Misty City Software), **119f**
 GradeQuick (Jackson Software), **119f**
 GradeSpeed (CampusWare), **119f**
 graphing calculators, 93–95. *See also* TI-73
 graphing calculator
 and data-collection probes, 23, 24
 use in planetary exploration, 57
 graphing data, 86
 Gregorian Calendar, 9
 Guardian, 106
 GuardiaNet, 106
- H**
 Halley, Edmund, 27
 Harrison, John, 5, 27
 Hawking, Stephen, 112
 Hazen, R. M., 2
 Headbone Zone, 106
 health, science and, 81
 history
 of flight, 68
 integrated to GPS navigation, 36
 of temperature recording, 20, 21
 volcanoes and, 63
 of water safety standards, 81
 How Things Fly (Smithsonian website), 67
 hydrogen maser clocks, 9
 hypotheses, scientific, 2
- I**
 Illinois schools, GIS in, 43
 ImagiProbe System, 24
 individualized education program (IEP), 111
 Individuals with Disabilities Education Act Amendments (1997), 111, 112
 Instructional Management System (EdSoft Software), **119f**
 interdisciplinary teaching, GIS related technologies and, 41, 43
 internet
 and bottled water information, 81
 consumer information sites, 85
 conversion tools on, **12f**
 data available on, 55–57
 flight and, 67–69
 on GPS-based education, 35
 information about heights, 94–95
 links for celestial observation tools, **32f**
 and mapping, 43
 nutrition, 86
 official time, 9
 science research on, 105–109
 searches on, 56–57
 technological applications, 5, 7
 and technology-based planetary exploration, 55
 and volcanoes, 63–64
 and weather forecasts, 59
 Internet Filter, The, 106
 iPAQ FlyJacket i3800, **102f**
- J**
 Jansenn, Zacharias, 75
 Java Jupiter, 31, **32f**
 Jefferson, Thomas, 11
 Jupiter
 finding, 31–33

Index

Galilean moons of, **32f**, 33–34

K

Kansas schools, GIS in, 42–43
 Ken-a Vision, 78
 KidsClick, 106
 Knott, Max, 75
 Kovich, F. J., 1
Krakatoa: The Day the World Exploded—August 27, 1883 (Winchester), 64

L

LabPro, 24
 labs
 CAI and experiments, 122
 on Onset Computer Corp’s website, 23
 Virtual Lab Series (Edmark), 111
 latitude, concept of, 35
 laws, scientific, 2
 LectureMate, **100f**
 Lesson Plan (PC), **100f**
 lesson plans
 on meteorology, 51
 on oceanography, 47, 48
 SOAR and, 77
 on volcanoes, 64
 Lilienthal, Otto, 67
 Logger Lite Software, 60, **61f**
 longitude
 calculation of, 27–29
 concept of, 35
Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time (Sobel), 27, 28
 “Longitude” (A&E drama), 27, 28
 Louisiana State University, 76
 Lucking, R., 11, 121, 122
 Ludwig, G., 42
 Lycoszone, 106

M

Magellan GPS Companion for Palm, **37f**
 MapMachine, 44
 maps

 interactive, 43
 from U.S. Census Bureau, 4344
 MapTech mapserver, 44
 Massachusetts schools, GIS in, 42
 Mauriel, J., 11
 melting point, 15
 Merriam-Webster OnLine, 28
 meteorology, 19, 51–53
 global frequency and distribution of lightning, **53f**
 MetLinkInternational Weather Project, 52
 climograph image, **52f**
 Metric Conversion Act (1975), 11
 MicroGrade (Chariot Software), **119f**
 microscopes, handheld, 75–79
 Minnesota schools, GIS in, 42
 minorities in flight, 68
 models, scientific, 2–3, 55
 human torso model, **3f**
 Mount St. Helens
 lessons focused on 1980 eruption, 64
 VolcanoCam at, 63
 mousekeys, **114f**
 Mullineaux, Lauren, 47, 48
 multimedia references on volcanoes, 64–65
 Museum of Aviation (Robinson Air Force Base, Georgia), 68

N

NASA
 Aeronautics Internet Textbook, 68
 Glenn Research Center, 69
 Optical Transient Detector, 52
 Rainfall Model, 2–3, **3f**
 Spacelink, 69
 weather and climate site, 52
 National Council of Teachers of Mathematics (NCTM)
 Data Analysis and Probability Standard, 95
 on measurement conversions, 11
 Standards, 71
 National Education Technology Standards for Students, 39–40, 97, **98t**, 102–103, 108–109

- special education applications and, 113
 - National Geographic Society
 - MapMachine, 44
 - video on volcanoes, 64
 - National Institute of Standards and Technology (NIST), 9
 - National Oceanic and Atmospheric Administration (NOAA)
 - classroom materials on meteorology, 52
 - website developed with American meteorological Society, 47
 - National Research Council, 3
 - National Resources Defense Council, 82
 - National Sanitation Foundation, 81
 - National Science Education Standards, 11
 - celestial observations and, 34
 - Earth and space science as unifying concepts, 55
 - on exploratory approach, 55
 - food findings and, 87
 - GIS and, 45
 - GPS applications and, 39
 - graphing calculators and, 95
 - handheld microscopes and, 79
 - and inquiry, 71
 - internet-based research and, 108
 - longitude and, 29
 - oceanography and, 49
 - pH testing and, 91
 - science and technology, 7
 - science as inquiry, 6
 - use of data-collection tools and, 24–25
 - volcanoes and, 65
 - National Sea Grant Library, 47
 - National State Sea Grant, 47
 - Nature 2.0, 112
 - NCTM. *See* National Council of Teachers of Mathematics
 - Net Nanny, 106
 - Net Shepherd, 106
 - Newton, Isaac, 27
 - Newton's First Law of Motion, 2
 - Newton's Second Law of Motion, 2
 - NOAA. *See* National Oceanic and Atmospheric Administration
 - nutrition
 - energy calculations, **86f**, **87f**
 - fast-food fact finding and, 85–87
 - hamburgers data, **86f**
 - water analysis, 81–83
- ## O
- Ocean Explorer, 48
 - oceanography, 47–49
 - Ocean Sciences Teacher Resource Center, 47
 - onscreen keyboards, **114f**
 - Onset Computer Corp's HOBO Data Logger system, 23–24
- ## P
- Palm, Inc., 97
 - Palm Reader, 98
 - PalmWorld (shareware), 37, **37f**
 - Pasco's Probeware Kit for Palm Handhelds, 24
 - PBS website information on flight, 67
 - PC-Sky, **32f**
 - PDA-based GIS, **45f**
 - PDAs (personal digital assistants), 97–100
 - and data-collection probes, 23, 24
 - GPS software for, 36–37, **36f**, 38–39, **38f**
 - navigational software, 44
 - presentation packages, 101, **102f**
 - projecting, 101–103
 - stargazing software for, 31
 - Periodic Table for Palm OS®, **99f**
 - pH
 - defined, 89
 - testing soft drinks, 89–91
 - phase changes, 15–18
 - Physical Science Standard, Transfer of Energy, 65
 - physics, GIS and, 41
 - Physics Chronology (website), 21
 - Piaget, Jean, 5
 - Pinnacle (Excelsior Software), **119f**
 - Pitch Solo!, **102f**
 - Pitsco's "Electronic Sensor Kits with Computer Interface," 23

Index

- Planetarium v.2.1.1, **99f**
 - plotting data, 86
 - average distance of planets from the Sun, **56f**
 - box-and-whisker plots, 20, **20f, 73f, 94f**
 - scatter plots, **73f**
 - Popper, Karl, 1
 - PowerOne Scientific v. 2.0, **100f**
 - PowerPoint presentations, **102f, 103f**
 - principles, scientific, 55
 - Principles and Standards for School Mathematics, 71
 - data analysis and, 74
 - probes
 - Go! Temp probe, 60
 - probeware packages, 23–24
 - use of, for temperature tracking, 21
 - Vernier probes, 24, 89
 - problem-solving, computers and, 121
 - Project 2061, 59
 - Project Atmosphere Australia, 52
 - Project Oceanography, 48
 - Project SafeSide, 51
 - ProScope, 75–76, **76f**
 - Pupil CAM, 78, **78f**
- ## R
- real-time data
 - on oceanography, 48
 - Royal Meteorological Society, The, 52, 97
 - Ruska, Ernst, 75
 - Russ and Ryan EdWare, 118
- ## S
- San Diego Aerospace Museum, 68
 - scatter plots, **73f**
 - School Maestro III, 118, **118**
 - science, defined, 2
 - scientific inquiry, 1–8
 - key components of, **5f**
 - simplest forms of, **4f**
 - scientific method, beginnings of, 1
 - Scirus, 105, **106f**
 - Scope on a Rope (SOAR), 76–77, **76f**
 - screen magnifiers, **115f**
 - screen reading and talking browsers, **115f**
 - Scripps Institution of Oceanography, 47, 48
 - search engines for science research, 105–109
 - Secrets of the Ocean Realm (PBS series)
 - website, 47
 - Shahan, R. W., 1
 - SimpleChart v. 1.1, **100f**
 - simulations, 121, 122
 - single-switch technology, 112
 - Sky Chart, **32f**
 - Sky & Telescope*
 - Interactive Sky Chart, 31, 32
 - website screenshot, **33f**
 - Smart Filter, 106
 - SOAR (Scope on a Rope), 76–77, **76f**
 - Sobel, Dava, 27
 - software
 - for checking temperature, 60
 - and data-collection probes, 23
 - on flight, 68–69
 - for grading, 117–119
 - for PDAs, 97–98, **99f, 100f, 101**
 - solar system model, 57
 - special needs students, technologies for, 111–115
 - speech synthesizers, **115f**
 - spreadsheets
 - for student investigations of fast food, 85–86
 - use in planetary exploration, 57
 - Star Chart, **32f**
 - statistics, 71–72
 - calculation with TI-73, 93–94
 - descriptive statistics, **73f**
 - exploration in real-world situations, 93
 - for minerals and contaminants in water, 82
 - temperature readings and, 61, 62
 - Steam Properties v. 2.21, **100f**
 - student achievement, CAI and, 121, 122
 - Student Log v.1.0, **100f**
 - Surf Watch, 106
 - Swiftcam, 78, **78f**
 - Swift Microscopes, 78
 - switches, **115f**

T

TeacherEase (Common Goal Systems), **119f**
 technology-based inquiry, 7
 technology-based planetary exploration, 55–58
 plot of average distance of planets from the Sun, **56f**
 string lengths for solar system model, **57f**
 temperature forecasts, checking accuracy of, 59–62
 comparison of predicted and measured temperatures, **62f**
 data as spreadsheet, thermometer, and graph, **61f**
 Logger Lite's statistical feature, **61f**
 temperature readings recorded with Logger Lite, **61f**
 weather.com predicted readings, **60f**
 temperature scales, implications of, 21
 temperature tracking, 19–21
 TerraServer (Microsoft website), 44
 theories, scientific, 2, 55
 thermometers, implications of, 21
 ThinkWave Educator, 118, **118**
 Tiger Map Server, 44
 TI-73 graphing calculator (Texas Instruments), 93–95
 box-and-whisker plot, **94f**
 conversions, 13
 data collection, 72
 median and mode computations, **94f**
 one-variable statistics, **94f**
 sample data entry screen, **93f**
 and testing of pH of soft drinks, 89
 TI-Graph Link software, 95
 time, concept of, 9–10
 trackballs, **114f**
 Tracker, 39
 Trefil, J., 2
Trends in International Mathematics and Science Study, 21
 2sky software, 101, **103f**

U

United States Geological Survey, 64

universal unit of time, 9
 University of Iowa's Center for Global and Regional Environmental Research, 43
 U.S. Census Bureau, maps and data from, 44
 U.S. Geological Survey website, 43
 Usenet, 107

V

Vernier probes, 24, 89
 Video Flex, 78
 videos
 SOAR and, 77
 on volcanoes, 64
 Virginia schools, GIS in, 42
 Virtual Lab Series (Edmark), 111
 Visor, 97
 voice output technology, **115f**
 voice recognition systems, **114f**
 volcanoes, 63–65
 simulated eruption, **63f**, 64
 Volcanoes! (CD-ROM), 64–65
 Volcano! (video, National Geographic), 64
 Volcano Video Productions, 64
 Volcano World, 64
 Voyager VGA CF Card for Pocket PC + PC Card, **102f**

W

water analysis, 81–83
 bottled water mineral and contaminant content, **82f**
 calcium levels in bottled water, **83f**
 Weather Channel, The, 51
 Weather Classroom, 51
 WhyFiles, 105, **106f**
 Winchester, Simon, 64
 WinZip, 98
 women
 in flight, 68
 in oceanography, 47, 48
 WorldClimate weather database, 19
 Wright brothers, 67
 Wyland Ocean Challenge, 47, 48

Index

X

Xircom, 97

Y

Yahooligans, 106, **107f**

Z

Zeeks, 106