Technology-Based Inquiry for Middle School

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Edwin P. Christmann, Editor

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Contents

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.

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.

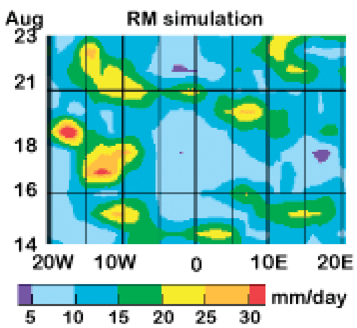
Scientific laws

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

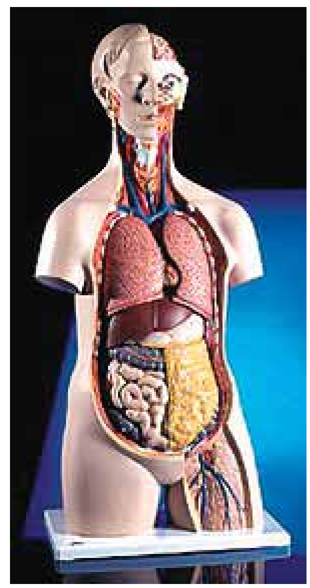
Figure 1 NASA Rainfall Model



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/*

Figure 2 Human Torso Model



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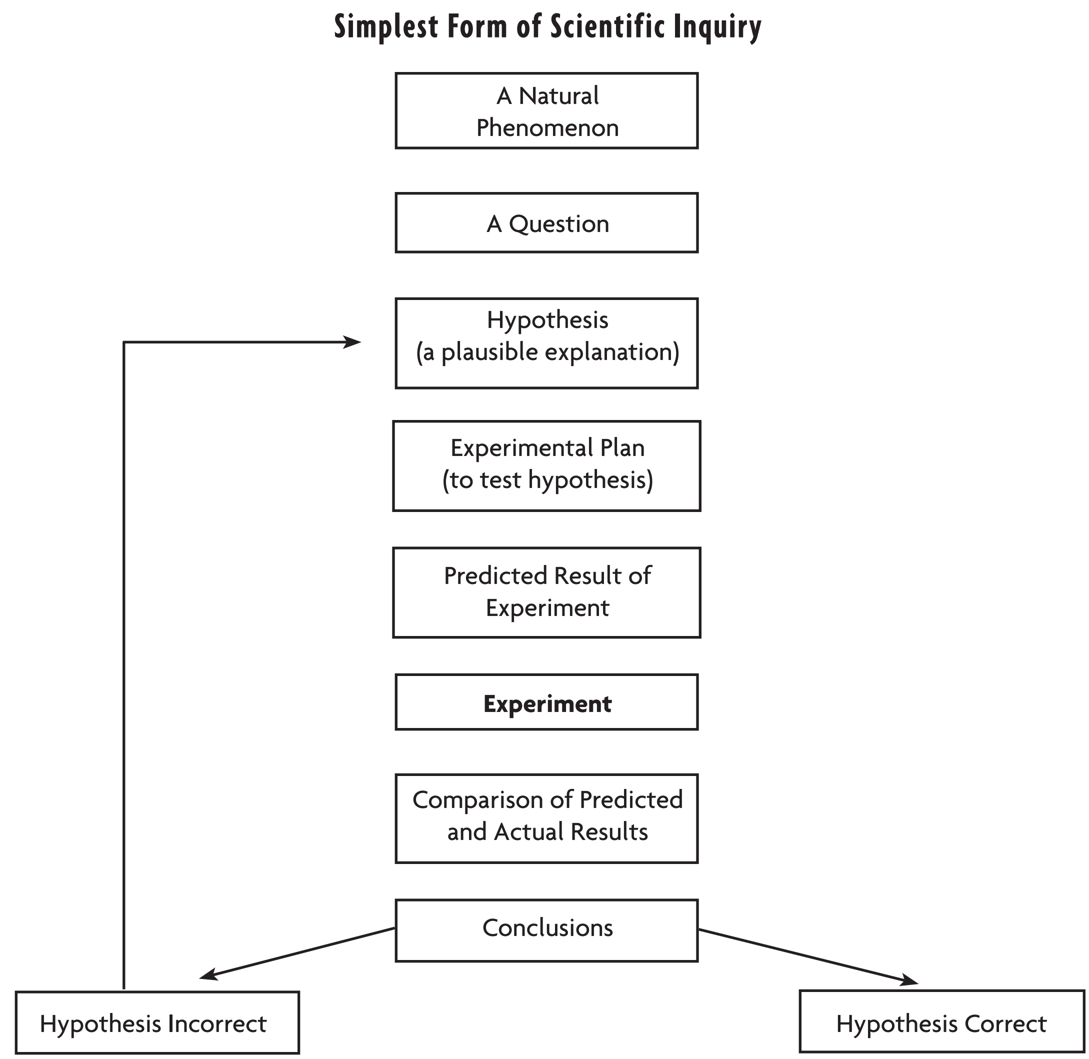
model. The computer-based model uses predictions based on past observations to fill in the data sets. Some other examples of scientific models are mixing baking soda and vinegar to simulate volcano eruptions, using marbles to represent gases, and examining a model of a human torso (see Figure 2). Subsequently, 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 hypothesis (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

Figure 3 Simplest Form of Scientific Inquiry



Adapted from *http://acept.la.asu.edu/courses/phs110/si/chapter1/main.html*.

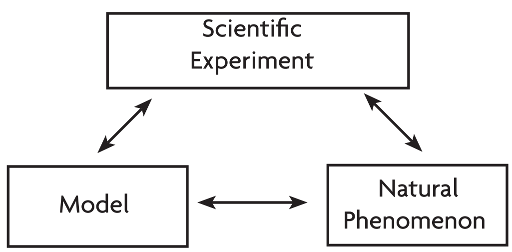
those taken in January and examine the variation between the results. Once the results have been gathered, a computer spreadsheet model with graphics can be used to show differences in factors that have caused temperature differences (e.g., direct sunlight time). Thus, models can be used to present additional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

Figure 4 Key Components of Scientific Inquiry

Key Components of Scientific Inquiry



Adapted from http://acept.la.asu.edu/courses/phs110/si/chapter1/main.html.

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: [hours/24 x 360 = 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

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	**Levels 5–6**	**Levels 9–12**
Abilities necessary to do scientific inquiry	Abilities necessary to do scientific inquiry	Abilities necessary to do scientific inquiry
Understanding about scientific inquiry	Understanding about 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 distinuish between natural objects and objects made by humans Understanding about science and technology	Abilities of technological design Understanding about science and technology	Abilities of technological design 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 systems (GIS), and other emerging technologies, science teachers can develop and integrate the skills that can make inquiry-based learning meaningful for 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 +/- 0.2°C. Teachers

Figure 1

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

Figure 3

Figure 4

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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