Vernier

WHITE PAPER

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What the Research Says About the Value of Probeware for Science Instruction

A Summary of Independent Research Prepared by Interactive Educational Systems Design, Inc. for Vernier Software & Technology

What the Research Says About the Value of Probeware for Science Instruction

Table of Contents

Top-Level Findings

Research and analysis presented in the sections that follow support the following findings:

1 Improved Test Scores

Use of technology tools for data collection, analysis, and visualization—capabilities supported by Vernier probeware and software—can provide a learning advantage to students, as evidenced in student test scores in science (National Center for Education Statistics, 2002, 2012; Schneider et al., 2002).

2 Deeper Understanding of Science Concepts

Use of technology tools for data collection, analysis, and visualization to teach scientific practices and support scientific investigations can help to deepen student understanding of science concepts.

- Research-informed expert opinion supports the value of probeware for improving student understanding of science concepts (Thornton, 2008; Webb, 2008).
- Based on their analysis of the research literature and of the capabilities of probeware, experts have identified specific "affordances" from use of probeware that support depth of student learning (Park & Slykhuis, 2008; Thornton, 2008).
- A variety of studies have shown that probeware can have a positive impact on the depth of students' science understanding when used in a context of scientific investigations that engage students in scientific practices (Linn & Hsi, 2000; National Research Council, 2006; Schneider et al., 2002; Thornton, 2008; Zucker et al., 2008).

3 Meeting National and State Instructional Standards

Student hands-on use of technology tools for data collection, analysis, and visualization is recommended in guidelines and requirements from influential national organizations and state standards.

- Use of probeware supports specific standards from the International Society for Technology in Education's *National Educational Technology Standards for Students* (ISTE, 2007).
- The Association for Science Teacher Education (ASTE) calls for use of probeware as part of science education (ASTE, n.d.).
- Educational standards and associated documents adopted by many states make reference to probeware; use of technology tools for data collection, analysis, and visualization; and/or integration of technology into science teaching and investigations.

4 Supporting a Framework for K–12 Science Education

Use of technology tools for data collection, analysis, and visualization in a context of student scientific investigations can provide experiences with core scientific practices for students, as called for in *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council, 2011).

Introduction

Active student involvement in scientific practices and procedures represents both a key goal of science instruction and an important means to help students build their scientific understanding. One way of doing this is through student hands-on use of *probeware*: that is, probes, sensors, and other technology tools, connected either to a computer system or to a stand-alone data-collection device, that are used for data collection, analysis, and (often) visualization of findings.

The origins of probeware date to the 1970s, when the first set of devices was created specifically for use in science classrooms (Park & Slykhuis, 2008, p. 37). Since the early 1980s, research has accumulated on the use of probeware—also sometimes referred to as *data logging or microcomputer-based laboratories (MBL)*—in classrooms ranging from the elementary through undergraduate levels.

Drawing on that body of research, this paper presents research-based evidence supporting the value of probeware as part of effective science instruction that can help raise student test scores, deepen student understanding of science concepts, and meet national and state instructional standards and recommendations—with a particular focus on middle school levels and higher.

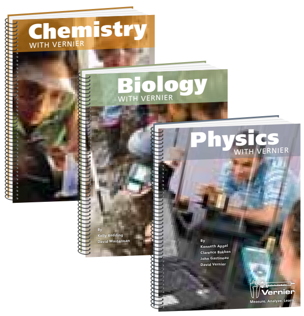
Vernier Probeware Products and Services

For more than 30 years, Vernier Software & Technology has been an innovator of scientific data-collection technology. Focused on science, technology, engineering, and mathematics (STEM), Vernier creates easy-to-use and affordable science interfaces, sensors, and graphing/analysis software, together with associated instructional resources for teachers and students.

Probes and Sensors

Vernier offers more than 70 probes that are appropriate for hands-on student use across a range of subject areas and grade levels. Selected examples related to specific subject areas are shown in the table below.

Selected Examples of Probes/Sensors	
Subject Area	**Probe/Sensor**
Biology	• Hand-Grip Heart Rate Monitor • Temperature Sensor • CO2 Gas Sensor • O2 Gas Sensor • SpectroVis Plus Spectrophotometer
Chemistry	• Gas Pressure Sensor • pH Sensor • Temperature Sensor • Conductivity Probe • SpectroVis Plus Spectrophotometer
Physical Science/ Physics	• Dual-range Force Sensor • Gas Pressure Sensor • Motion Detector • Temperature Sensor • Accelerometers



Software

Software from Vernier provides powerful capabilities for students to record, graph, and analyze data collected by the Vernier probes.

- Logger *Pro* software, available on Windows and Mac computers, is particularly well suited for classrooms with computers at each lab station. Capabilities of Logger *Pro* include the following:
  - Draw predictions on a graph before collecting data
  - Collect live data from the broad array of Vernier sensors and probes
  - Use a variety of data-collection modes as needed for students' experiments
  - Manually enter data for graphing and analysis
  - Capture videos from DV cameras and web cameras, and extract data from movies using frame-by-frame video analysis
  - Lay out graphs, tables, and text as needed to describe students' experiments using a variety of formats
  - Read values and slope from graphs
  - Model data with user-adjustable functions
- The LabQuest graphing and analysis application (LabQuest App), available on Vernier's LabQuest handheld devices, includes many similar capabilities. Additionally, it can do the following:
  - Collect, analyze, and share sensor data wirelessly on any device with a web browser
  - Connect wirelessly to iPads
  - Provide a field for students to take notes
  - Facilitate voice annotation with internal microphone
  - Export data to Logger *Pro*

Instructional Resources

More than 25 lab books are available from Vernier. These provide teacher and student guidance in more than 400 well-tested experiments that are designed to give students firsthand experience with the scientific practices of collecting and analyzing data in the context of conducting investigations. Additionally, embedded tutorials within Logger *Pro* guide students in specific data-collection and analysis procedures.

Examples of Vernier Probeware Use as Part of Science Instruction

Specific examples illustrating some of the ways Vernier probeware can be used effectively as part of science instruction are provided below. Typically, students work in groups to complete these activities, under the guidance of an instructor. These examples are all based on experiments described in Vernier lab books.

Students in Middle School Through College Using a Vernier Motion Detector (Physics)

The Vernier Motion Detector used with Logger *Pro* software or LabQuest App enables students to examine the behavior of moving objects at a variety of levels. "Graphing Your Motion-Position Matching," an activity from the *Middle School Science with Vernier* lab book, is well suited for middle school students learning about concepts such as position and velocity.

In this activity, students stand in front of a motion detector and are challenged to move in such a way that their position-time behavior matches a graph supplied by the software, such as the one below. As students move, their motion is superimposed on the graph. While viewing the graph of their own motion in real time, students adjust their motion to more closely match the sample provided. Students quickly realize that the slope of the graph gives a clue about how rapidly they are moving.

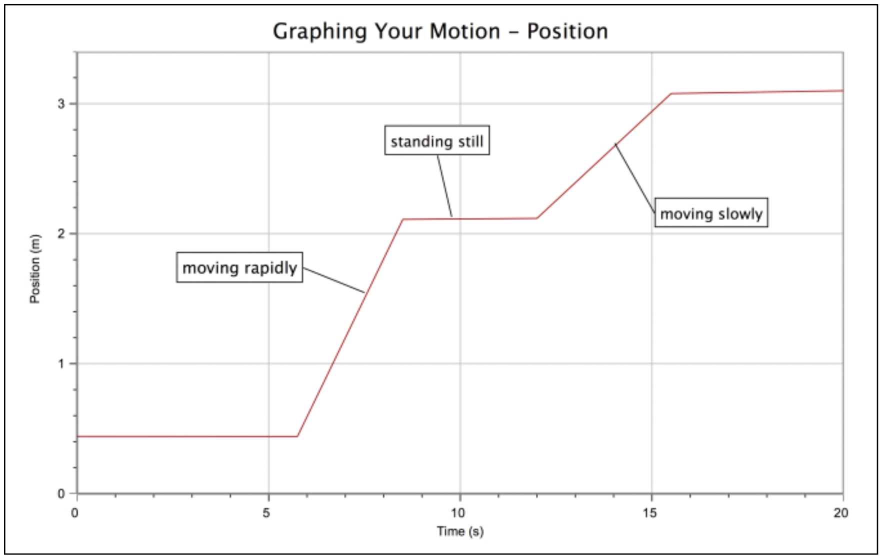


Figure 1. Sample Motion Graph for Students to Match

As part of the study of kinematics in a high school or introductory college level physics class, students can examine the position-time and velocity-time behavior of a cart moving up and down an inclined track, or use the velocity-time data during collisions between carts in the study of conservation of momentum.

High School Students Using a CO_2 Gas Sensor (Biology)

Use of a CO_2 Sensor enables high school students to investigate factors affecting cell respiration in germinating peas. This iconic experiment in AP biology is difficult to perform at best without such a sensor. The software generates a graph that shows that the concentration of CO_2 expired increases steadily; the slope of the graph is an indicator of the rate at which the peas respire.

High School Students Using a Gas Pressure Sensor (Chemistry)

Students can use a Gas Pressure Sensor in a chemistry class to investigate the relationship between the pressure and volume of the air in a syringe. Using the curve fitting tools in Vernier graphing and analysis software, students can show that the pressure of the gas is inversely proportional to its volume.

High School or College Students Using a pH Sensor (Chemistry)

Students in high school or introductory college chemistry can use a pH Sensor in an acid-base titration. While pH sensors have been used for decades, the analytical tools in Logger *Pro* and LabQuest App enable students to graph their data so they can examine the *rate of change* of the pH at various points along the titration curve. This information helps them understand *why* the inflection point in the plot of pH versus volume of titrant represents the endpoint of the titration.

About This White Paper

This white paper includes the following informative sections:

- Top-level findings summarized from the body of research (p. 3)
- Description of research supporting the value of probeware for improving student test scores in science
- Description of research supporting the value of probeware for promoting deeper student understanding of science concepts
- Description of how probeware addresses guidelines and requirements from influential national organizations and state standards
- Description of how probeware supports instructional practices recommended in *A Framework for K–12 Science Education*
- Conclusion

1

Improved Test Scores

Research suggests that use of technology tools for data collection, analysis, and visualization—the kind of use promoted by Vernier probeware and software—can provide a learning advantage to students, as evidenced in student test scores in science.

Correlation of NAEP Scores to Student Use of Probes, Computers, and Related Technology

Data from the 2000 National Assessment of Educational Progress (NAEP) indicated a correlation between student test scores in science and the use of probes and other technology tools to collect and analyze data. According to the National Center for Education Statistics (2002):

> Twelfth-grade students were asked how frequently they used computers to collect data using probes, download data, analyze data, or exchange information via the Internet. Of the two-thirds of the 12th grade sample taking a science course in their senior year, those who reported using computers to collect data, download data, or analyze data had higher scores than students who reported never doing so. More frequent use (1-2 times per month) of computers to collect data or to analyze data was also associated with higher scores than less frequent use (less than once a month). (p. 12)

More specifically:

- Among students taking science courses during their senior year, those who *collected data using probes* 1–2 times per month scored significantly higher than those who did so less than once a month, who in turn scored significantly higher than those who never collected data using probes (p. 12).
- Among students taking science courses during their senior year, those who *used computers to analyze data* 1–2 times per month scored significantly higher than those who did so less than once a month, who in turn scored significantly higher than those who never used computers to analyze data (p. 12).

Data from the 2009 NAEP confirmed a learning advantage in science for 12th grade students who use computers for science, although these results were not correlated to ways that computers and related technology were used as had been done for the 2000 data. Specifically, 12th graders who reported that they used computers at least once every few weeks for science during that school year scored significantly higher than those who reported that they used computers for science never or hardly ever (National Center for Education Statistics, 2012; see the Appendix for details of the process that was used to obtain these statistics).

While these findings are correlational and thus do not demonstrate causation, they are highly suggestive regarding the value of computers and related technology—including probes—as part of high school science instruction.

Improved Test Scores from Curriculum That Incorporates Probeware

Schneider et al. (2002) compared the performance on a publicly released version of the NAEP Science Test of 10th and 11th grade students who had been using a project-based science (PBS) curriculum for two to three years with the officially reported national NAEP scores. They found:

- Across the entire set of NAEP items, PBS students significantly outperformed the total national sample, the "white" subgroup, and the "not eligible for free lunch" subgroup—the two subgroups that most closely matched the PBS students.[1]
- Based on analysis of the individual test items, PBS students significantly outperformed the total national sample on 59% of the items. They significantly outperformed the "white" subgroup on 44% of the items, and the "not eligible for free lunch" subgroup on 50% of the items.[2]

The PBS curriculum consisted of units incorporating activities that "engage students in investigating a real-life question or problem that drives activities and organizes concepts and principles" (p. 411). Technology, including probeware, was an integral part of the experience: "Students used computers as tools to gather information through telecommunications and probeware, analyze data, express results graphically or pictorially, create scientific models, and write reports" (p. 414). In short, this project-based curriculum represented an example of the kind of instructional environment in which students would be expected to use probeware of the type provided by Vernier in order to collect, analyze, and visualize data.

[1] "The multivariate analysis indicated a statistically reliable difference between the groups across all 34 items, Pillai's trace=.800; F=125.98; p<.001." (p. 416).

[2] $p < .05$. Table 2, p. 418.

2

Deeper Understanding of Science Concepts

Research shows that use of technology tools for data collection, analysis, and visualization to teach scientific practices and support scientific investigations can help to deepen student understanding of science concepts. This greater depth of student understanding is attested by research-informed expert opinion and relates to specific affordances offered by this technology that contribute to effective science instruction. Additionally, specific research studies provide evidence of improved student understanding when probeware is used to support scientific investigations carried out by students.

Research-Informed Expert Opinion on the Value of Probeware

In a 2008 international handbook of information technology in primary and secondary education, the author of a chapter on the impact of instructional technology on science education identified data logging (a term for probeware use that is commonly used internationally) as among the "[t]ypes of IT use that have been shown to promote science learning" (Webb, 2008, p. 134). Benefits mentioned by Webb included ease of use, time saving (citing Barton, 1997), greater understanding based on real-time data collection (citing Linn & Hsi, 2000), support for "deep learning" from student interactions with the technology and associated student-student interactions (citing Russell et al., 2004), and freeing up science teachers to "circulate and stimulate discussion and thinking about the results" (p. 138, citing Rogers & Finlayson, 2004).

In his description of research evidence related to effective computer supported instruction in physics, Thornton (2008) cited Euler & Müller (1999) as reporting that microcomputer-based laboratories (another term for probeware use) were "the only method of using computers in physics curricula that has a proven positive learning effect" (p. 5). Summarizing the body of research evidence, Thornton stated:

> [R]eal-time data logging introduced into a traditional environment results in more conceptual learning than the traditional environment but much less learning than an activity-based, research-based environment supporting peer learning. (p. 18)

These activity-based, research-based environments mentioned by Thornton are described in more detail under Use of Probeware to Support Scientific Investigations on pp. 11–12.

Affordances from Probeware

Based on their analysis of the research literature and of the capabilities of probeware, several researchers have identified specific "affordances" from use of probeware, described as "advantages...to science learning and inquiry" (Park & Slykhuis, 2008, p. 34; see also Thornton, 2008). For example, according to a chapter on framing the research on technology and student learning in science education:

> Probeware...enables students to collect and graph data, bypassing a number of mundane manual procedures. Accompanying software allows students to discover possible mathematical relationships among variables using curve-fitting programs. (Park & Slykhuis, 2008, p. 34)

Thornton's (2008) research summary identified the following "advantages [that] well-designed real-time data logging tools bring to appropriately structured, research-based curricula" (p. 5):

- "Real-time data logging tools can allow students to find answers directly from the physical world." (p. 6)
- "Real-time data logging tools can make the 'abstract' concrete through immediate feedback...linking...a concrete measurement of an actual physical

system with the simultaneous production of the symbolic representation"—for example, via graphing. (p. 6)

- "Real-time data logging tools in the right curricular context may improve certain types of spatial ability" (p. 7). In particular, Thornton cited evidence that data logging improves students' spatial visualization, an important skill in solving physics problems (pp. 16–17, citing Kozhevnikov & Thornton, 2006).
- "Real-time data logging tools can encourage learning from peers." (p. 7)
- "Real-time data logging tools can encourage critical thinking skills by reducing the drudgery of data collection and manipulation." (p. 7)
- "Real-time data logging tools are usable by the novice as well as the more advanced student." (p. 7)

Use of Probeware to Support Scientific Investigations

A variety of studies have shown that probeware can have a positive impact on the depth of students' science understanding when used in a context of scientific investigations that engage students in scientific practices. The instructional importance of scientific practices in a context of investigations has been explained by Rodger Bybee as follows:

> When students engage in scientific practices, activities become the basis for learning about experiments, data and evidence, social discourse, models and tools, and mathematics and for developing the ability to evaluate knowledge claims, conduct empirical investigations, and develop explanations. (Bybee, 2011)

Specific instructional settings for the use of probeware described by the researchers below vary, but all fit within this description as engaging students in scientific practices in a context of investigations.

Thornton (2008)

As noted above, Thornton's (2008) summary of research on effective computer supported physics instruction identified substantially greater learning from probeware in "activity-based, research-based environment[s] supporting peer learning" (p. 18). More specifically, he argued that this kind of environment was vital if use of probeware was to result in conceptual learning on the part of students:

> From the number and variety of instances where using real-time data logging led to increased student understanding, an educator might be tempted to think that just adding real-time data logging to a traditional setting with no substantial curricular changes will result in dramatic learning increases. In fact, the use of real-time data logging in the traditional laboratory, which is largely concerned with equation verification, can improve the laboratory in the sense that students can make more accurate measurements, more quickly recognize experimental procedural errors, take data more quickly, use the analysis tools to evaluate the data, and make use of other affordances...However, such laboratories rarely result in increased conceptual understanding. (p. 12)

Thornton summarized research showing "substantial conceptual learning gains" from three related physics curricula that "employ real-time data logging tools in an activity-based environment, ...examine the physical world for answers, ...use peer interaction, [and] are research-based" (p. 9).[3] As defined by Thornton, "activity-based" means that "[t]he methods used and the learning environment actively engage students in learning the concepts on which the curriculum focuses" (p. 2), while "research-based," means that the curriculum

> uses the methods of physics education research to select and order the content. Student learning is evaluated using multiple methods and the curriculum is altered

[3] The curricula were RealTime Physics, Workshop Physics, and Interactive Lecture Demonstrations.

> to improve learning. The curriculum pays attention to what students know at the time of instruction and starts instruction with what students know. There is most often a focus on conceptual understanding but not to the detriment of algorithmic or quantitative learning. (p. 2)

Specifically, use of these instructional programs resulted in substantially larger gains on the Force and Motion Conceptual Evaluation (FCME), compared to other instructional settings where traditional instruction was used. Additionally, students retained and may have built upon their understanding after instruction had ended:

> Whenever questions from the FMCE were asked again up to six weeks after instruction in dynamics had ended, the percentage of students answering in a Newtonian way increased rather [than] decreased, as is often the case when conceptual knowledge is considered. We attribute this increase to assimilation of the concepts. (p. 11, citing Thornton & Sokoloff, 1998)

Thornton cited another study that found strong retention of conceptual understanding more than two years after students had experienced the instruction (p. 12, citing Bernhard, 2001).

Schneider et al. (2002)

As described above, Schneider et al. (2002) found that use of a project-based science (PBS) curriculum incorporating probeware resulted in improved test scores on a publicly released version of the NAEP Science Test. Analysis of the results suggested that these results included improved conceptual understanding. In general, the longer the response required by the question, the better the PBS students did in comparison to the national sample. The authors wrote:

> When we examine the types of questions for which PBS students scored higher, the percentage of items for which PBS students scored significantly higher increased as the length of the response increased. (p. 419)

Specifically, in extended open response items—the type of items where students would be required to demonstrate deep conceptual understanding—the PBS students performed much better than the national sample.[4]

Zucker et al. (2008)

Zucker and colleagues (2008) described findings from the Technology Enhanced Elementary and Middle School Science II project (TEEMSS), which featured

> inquiry-based instructional science units for teaching in grades 3–8. Each unit uses computers and probeware to support students' investigations of real-world phenomena using probes (e.g., for temperature or pressure) or, in one case, virtual environments based on mathematical models. (p. 42)

Comparing student learning from TEEMSS units with learning the previous year by students completing similar instruction with the same teacher but not using TEEMSS, the researchers found that the TEEMSS students significantly outperformed the non-TEEMSS students on unit tests for 4 out of 8 units, with effect sizes ranging from 0.49 to 1.54 (p. 46). The researchers speculated that students might have benefitted more from incorporation of sensors and probeware in units dealing with science topics where graphs are important for conceptual learning (p. 47).

[4] PBS students scored significantly higher ($p < .05$) than the not eligible for free lunch and white groups on 75% of the extended constructed response items (p. 419).

Computer as Learning Partner (Linn & Hsi, 2000)

Linn and Hsi (2000) described 15 years of experience with the Computer as Learning Partner (CLP) project, which taught science to middle school students in an ongoing design study context. The project used an approach that incorporated probeware and simulations as part of hands-on student investigations of personally relevant problems related to students' existing understanding of science concepts, focusing initially on heat and temperature—a topic that is inherently difficult for students at this level, and remains difficult even for many adults with scientific training (Linn & Hsi, 2000, p. 58).

By the eighth semester, students in the program experienced dramatic improvement in their understanding of heat and temperature concepts (Linn & Hsi, 2000, p. 53). The researchers also found that "students are much better at interpreting the findings of their experiments when they use real-time data collection than when they construct their own graphs" (p. 64), suggesting a specific advantage to using probeware with real-time graphing for student experiments.

Positive results persisted in high school. According to the authors:

> [S]tudents who had participated in CLP were far more successful at understanding heat and temperature than their non-CLP counterparts...Specifically, the understanding of the twelfth grade students who had studied the typical curriculum resembled that of the CLP students at the beginning of the eighth grade [prior to the CLP instruction]. (pp. 353–354)

Reviewing data for these students from the National Assessment for Educational Progress, researchers found that CLP "had little effect on multiple choice items that required recall," but that "on items requiring interpretation, CLP students outperformed comparable eighth graders and older students. The CLP students also performed better on some items requiring interpretation of graphs" (p. 354).

America's Lab Report (National Research Council, 2006)

America's Lab Report, a 2006 report commissioned by the National Science Foundation about the current status of and future directions for the role of high school science laboratories in science education, distinguished between traditional (i.e., "typical") lab experiences and what the report referred to as integrated instructional units:

> Historically, laboratory experiences have been disconnected from the flow of classroom science lessons. Because this approach remains common today, we refer to these separate laboratory experiences as "typical" laboratory experiences. . . . [In contrast, i]ntegrated instructional units connect laboratory experiences with other types of science learning activities, including lectures, reading, and discussion. Students are engaged in framing research questions, making observations, designing and executing experiments, gathering and analyzing data, and constructing scientific arguments and explanations. (National Research Council, 2006, p. 4)

While noting the scarcity of research on integrated instructional units, the report stated: "The studies conducted to date indicate that [integrated instructional units] show greater effectiveness [in] improving mastery of subject matter, developing scientific reasoning, and cultivating interest in science," compared to "more traditional forms of science instruction" (p. 5). Among the promising, research-supported examples of effective integrated instructional units cited by the report was the Computer as Learning Partner project described above, which incorporated probeware as an important instructional component (pp. 84–85).

Describing the desired outcomes of laboratory experiences, the authors of *America's Lab Report* identified several areas where hands-on student experience with tools for scientific investigation such as those provided by Vernier plays an important role in learning. With respect to the goal of students "[u]nderstanding the complexity and ambiguity of empirical work," they wrote:

> Laboratory experiences may help students learn to address the challenges inherent in directly observing and manipulating the material world, including troubleshooting equipment used to make observations, understanding measurement error, and interpreting and aggregating the resulting data...Students' direct encounters with natural phenomena in laboratory science courses are inherently more ambiguous and messy than the representations of these phenomena in science lectures, textbooks, and mathematical formulas...[L]aboratory experiences may be the only way to advance the goal of helping students understand the complexity and ambiguity of empirical work. (pp. 77–78)

Similarly, with respect to the goal of students "[d]eveloping practical skills," they wrote:

> In laboratory experiences, students may learn to use the tools and conventions of science. For example, they may develop skills in using scientific equipment correctly and safely, making observations, taking measurements, and carrying out well-defined scientific procedures. (p. 77)

3

Meeting National and State Instructional Standards

Student hands-on use of technology tools for data collection, analysis, and visualization is recommended in guidelines and requirements from influential national organizations and state standards, as described below.

ISTE National Educational Technology Standards (NETS)

Included among the standards issued by the International Society for Technology in Education (ISTE) describing "the skills and knowledge students need to learn effectively and live productively in an increasingly global and digital world" are several that relate directly to the capabilities of probeware (ISTE, 2007).

- **Standard 3: Research and Information Fluency** of the NETS for Students 2007 calls for students to "apply digital tools to gather, evaluate, and use information." More specifically, students are to "process data and report results" (sub-standard d). These activities are directly supported by Vernier probeware and its associated software, which provide the capability to collect, process, and report data resulting from their observations and experiments.
- **Standard 4: Critical Thinking, Problem Solving, and Decision Making** calls for students to "collect and analyze data to identify solutions and/or make informed decisions" (sub-standard c). Tutorials that accompany Logger *Pro* software and activities suggested by the Vernier lab books guide teachers and students in collecting and analyzing data as part of a decision-making process.

ASTE Position Statement on Technology in Science Teacher Education

As part of its position statement on technology in science teacher education, the Association for Science Teacher Education (ASTE) identified "real-time data collection with probeware" as one of a number of technologies that "offer science teachers new opportunities for creating learning environments that meet the needs of diverse learners" (ASTE, n.d.). Among specific "examples of how technology-based materials may be used to promote science teaching and learning" were the following:

- "Support student investigations with real-time data collection via hand-held or microcomputer-based probeware."
- "Use scientific visualizations to show phenomena that cannot be seen with typical classroom resources."

Vernier software provides visualizations in a variety of formats based on data students collect using probeware as part of their science investigations.

State Standards

Educational standards and associated documents adopted by many states make reference to probeware; use of technology tools for data collection, analysis, and visualization; and/or integration of technology into science teaching and investigations. Specifically, looking at standards and associated documents for 50 states plus the District of Columbia:

- Fourteen sets of standards mention probes, sensors, probeware, and/or electronic/digital or handheld data-collection devices.
- Forty mandate or recommend student use of technology tools in order to observe, measure, and/or collect data.
- Twenty mandate or recommend student use of technology tools to present, report, or display data.
- Twenty-seven mandate or recommend student use of technology tools to analyze data.
- Twenty-three mandate or recommend that students select and/or make decisions about appropriate use of technology tools in scientific investigations.
- Forty-four mandate or recommend that students use technology in connection with scientific investigations and/or problem solving.
- Forty-five mandate or recommend integrating technology into science teaching in some fashion.

The table on the following page shows which states' standards address each of the instructional uses of technology listed above.

	References to probes, sensors, probeware, etc.	Students use tech to observe/ measure/ collect data	Students use tech to present/ report/ display data	Students use tech to analyze data	Students select and/or make decisions about tech in scientific investigations	Students use tech in scientific investigations and/or problem solving	Integrate technology into science teaching (total)
Alabama							✔
Alaska							
Arizona	✔	✔			✔	✔	✔
Arkansas	✔	✔				✔	✔
California	✔	✔	✔	✔	✔	✔	✔
Colorado							
Connecticut							
Delaware		✔			✔	✔	✔
District of Columbia	✔	✔	✔	✔	✔	✔	✔
Florida		✔	✔	✔		✔	✔
Georgia		✔	✔	✔		✔	✔
Hawaii		✔	✔	✔		✔	✔
Idaho		✔				✔	✔
Illinois		✔	✔	✔		✔	✔
Indiana		✔				✔	✔
Iowa		✔		✔	✔	✔	✔
Kansas		✔		✔	✔	✔	✔
Kentucky	✔	✔	✔	✔	✔	✔	✔
Louisiana		✔	✔	✔	✔	✔	✔
Maine		✔		✔		✔	✔
Maryland							
Massachusetts	✔	✔			✔	✔	✔
Michigan		✔			✔	✔	✔
Minnesota		✔			✔	✔	✔
Mississippi	✔	✔	✔	✔		✔	✔
Missouri		✔				✔	✔
Montana		✔		✔	✔	✔	✔
Nebraska		✔			✔	✔	✔
Nevada		✔		✔	✔	✔	✔
New Hampshire	✔	✔	✔	✔	✔	✔	✔
New Jersey		✔	✔	✔		✔	✔
New Mexico		✔	✔	✔	✔	✔	✔
New York	✔	✔	✔	✔		✔	✔
North Carolina		✔	✔	✔	✔	✔	✔
North Dakota						✔	✔
Ohio	✔	✔		✔		✔	✔
Oklahoma	✔	✔				✔	✔
Oregon							
Pennsylvania		✔		✔		✔	✔
Rhode Island					✔	✔	✔
South Carolina						✔	✔
South Dakota			✔		✔	✔	✔
Tennessee		✔		✔	✔	✔	✔
Texas	✔	✔			✔	✔	✔
Utah							
Vermont	✔	✔				✔	✔
Virginia	✔	✔	✔	✔	✔	✔	✔
Washington		✔	✔	✔		✔	✔
West Virginia		✔	✔	✔		✔	✔
Wisconsin		✔	✔	✔	✔	✔	✔
Wyoming		✔	✔	✔		✔	✔

4

Supporting *A Framework for K–12 Science Education*

As described in the introduction to this white paper, Vernier provides a wealth of technology tools for data collection, analysis, and visualization. Use of such technology tools in a context of student scientific investigations can provide experiences with core scientific practices, as called for in *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.

Dimensions of A Framework for K–12 Science Education

As a step toward the next generation of K–12 science education standards in the U.S., in 2011 the National Research Council released *A Framework for K–12 Science Education*. This document, reflecting findings from science education research, products of previous standards development efforts, and input from numerous stakeholders in science education, focuses on student learning across three broad dimensions:

- "Scientific and engineering practices;
- "Crosscutting concepts that unify the study of science and engineering through their common application across fields; and
- "Core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and the applications of science." (p. ES-1)

This section describes how Vernier probeware and its supporting materials can be used to support key scientific practices from the *Framework.*

Supporting an Instructional Context for Scientific Practices

The *Framework* identifies eight practices as "essential elements of the K–12 science and engineering curriculum":

"1. Asking questions (for science) and defining problems (for engineering)

"2. Developing and using models

"3. Planning and carrying out investigations

"4. Analyzing and interpreting data

"5. Using mathematics, information and computer technology, and computational thinking

"6. Constructing explanations (for science) and designing solutions (for engineering)

"7. Engaging in argument from evidence

"8. Obtaining, evaluating, and communicating information" (pp. 3–5 to 3–6)

Subsections below describe specific ways that Vernier probeware can be used to support Practices 3, 4, 5, and 8 listed above. In a more general sense, by facilitating student investigations using real-world data, Vernier probeware supports an instructional context where students can gain experience with all eight science practices.

Practice 3. Planning and Carrying Out Investigations

Describing the goals associated with this practice, the *Framework* specifies that by grade 12, students should be able to do the following:

- "Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis for an expected outcome based on a model or theory.
- "Decide what data are to be gathered, what tools are needed to do the gathering, and how measurements will be recorded.
- "Decide how much data are needed to produce reliable measurements and consider any limitations on the precision of the data.
- "Plan experimental or field-research procedures, identifying relevant independent and dependent variables and, when appropriate, the need for controls.
- "Consider possible confounding variables or effects and ensure that the investigation's design has controlled for them." (pp. 3–10)

Vernier probeware and its associated software tools can be used to support investigations that address all of these goals. Examples of activities that can support these goals are provided in the various Vernier lab books. Additionally, exposure to and experience with a variety of measurement tools in a variety of investigative contexts can help provide students with the necessary knowledge to make informed decisions regarding investigation design—particularly related to the second and third goals listed above on data gathering and use. Use of tools similar to those actually used by scientists, such as those provided by Vernier, can help students in learning to think like scientists, particularly with respect to the role of data collection and measurement as part of investigations.

Practice 4. Analyzing and Interpreting Data

Vernier probeware provides substantive support for five of the six goals related to this practice specified in the *Framework* as tasks students should be able to carry out by grade 12:[5]

- "Analyze data systematically, either to look for salient patterns or to test whether the data are consistent with an initial hypothesis.
- "Recognize when the data are in conflict with expectations and consider what revisions in the initial model are needed.
- "Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output.
- "Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.
- "Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships." (pp. 3–12)

More information on how Vernier probeware supports these goals is provided below.

Extended Data Collection

In connection to Practice 4, a potential use for information technology identified in the *Framework* is to "[enable] the capture of data beyond the classroom at all hours of the day. Such data sets extend the range of student experience and help to illuminate this important practice of analyzing and interpreting data" (pp. 3–11 to 3–12). This potential is realized by the Data Matrix feature of the LabQuest App, which expedites the collection of data at multiple locations and/or over multiple days, all in the same data file.

[5] The sixth goal, "Collect data from physical models and analyze the performance of a design under a range of conditions," relates specifically to engineering practices.

INSTRUCTIONAL EXAMPLE

Use of Vernier Probeware to Collect Data Outside the Classroom and/or Beyond the School Day

Capabilities of LabQuest App's Data Matrix feature are especially useful in an environmental science course. The sample screen capture to the right shows readings from multiple sensors at a given site.

Students can also adjust the data-collection parameters in Logger *Pro* and LabQuest App to allow the program to collect data from sensors over an extended period of time. This configuration would enable them to conduct experiments such as measuring the concentrations of O_2 and CO_2 gases in an enclosed space containing plants to study the effect of illumination on photosynthesis.

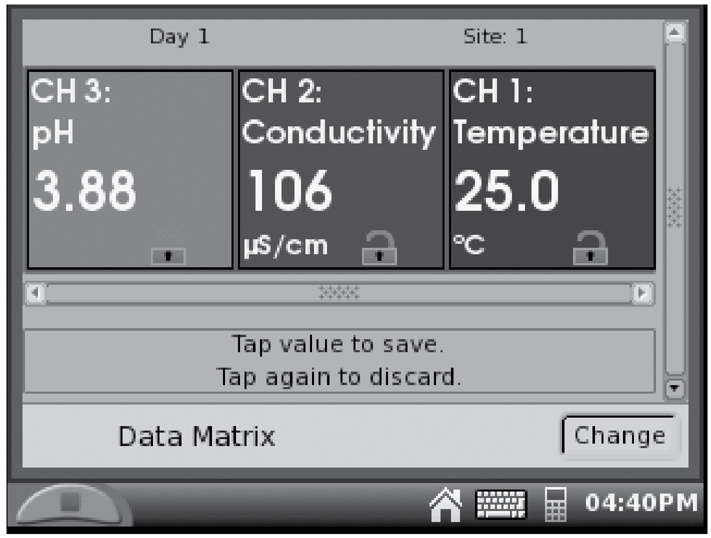


Figure 2. Data Matrix in LabQuest App

Technology Tools for Visualization

Use of Vernier probeware and its associated software directly involves students in carrying out the third goal associated with Practice 4:

- Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output.

With respect specifically to visualization, the *Framework* notes:

> Tables permit major features of a large body of data to be summarized in a conveniently accessible form, graphs offer a means of visually summarizing the data, and mathematics is essential for expressing relationships between different variables in the data set...Modern computer-based visualization tools often allow data to be displayed in varied forms and thus for learners to engage interactively with the data in their analyses. (pp. 3–11)

Vernier probeware is well suited to provide this kind of support. The instructional examples below illustrate the power of graphical visualization, the potential for students to analyze the data in order to express the data mathematically, and the capabilities of the software to express data in both table and graph format.

INSTRUCTIONAL EXAMPLE

Use of Vernier Probeware for Visualization: Exploring Acceleration Using Two Graphs

Consider the case of students in a physics class using a Motion Detector to measure the position of a cart as it rolls up and down an inclined track. The software allows the student to perform a curve fit on the position versus time graph (Figure 3) and to examine a linear fit to the plot of velocity versus time (Figure 4).

Knowing that acceleration is the rate of change of velocity, students can first observe that Figure 4 shows that the cart is accelerating uniformly, then use the slope of the linear fit to find the value of acceleration (in this case -0.318 m/s/s). When they examine the value of the *A* parameter of the curve fit in Figure 3 (-0.159), they find that it is one-half of the acceleration. This sets up the derivation of the standard equation describing the position of an object undergoing uniform acceleration:

$$x = \tfrac{1}{2}at^2 + v_0 t$$

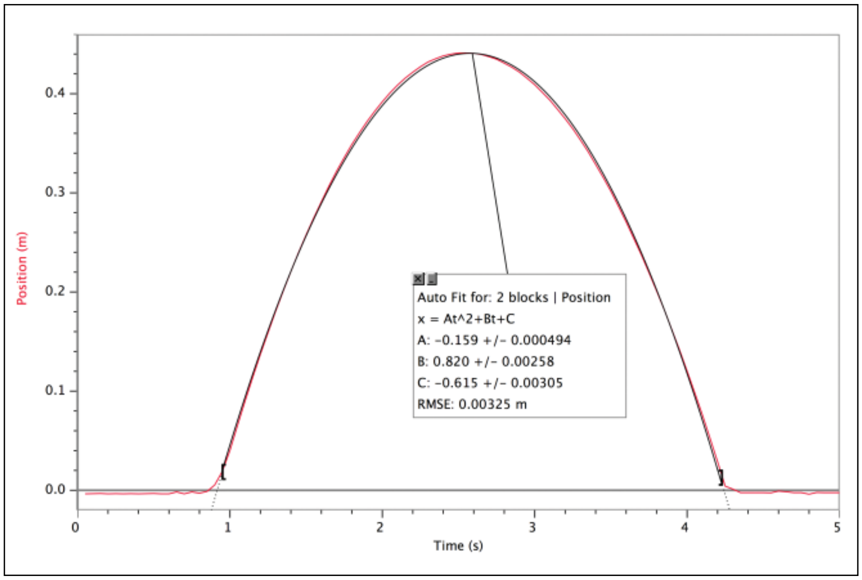


Figure 3. Position vs. Time

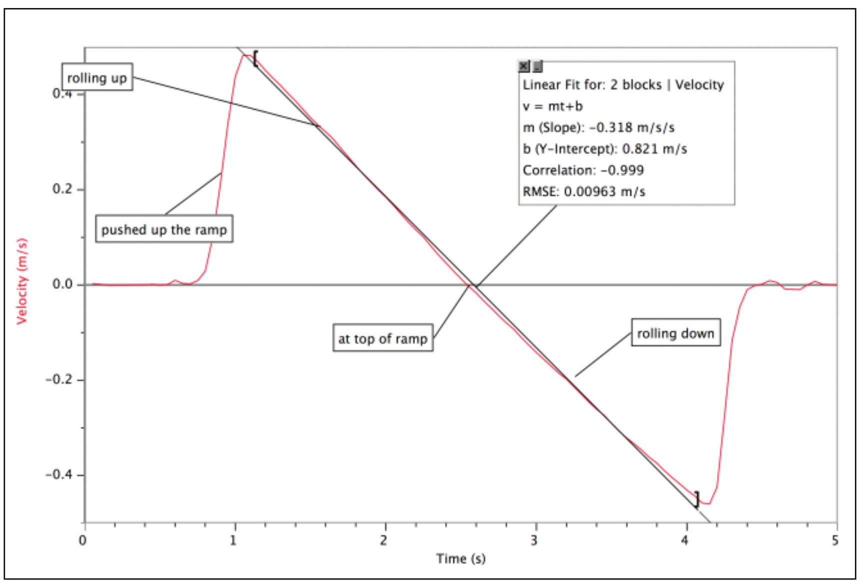


Figure 4. Velocity vs. Time

INSTRUCTIONAL EXAMPLE

Use of Vernier Probeware for Visualization: Exploring Harmonic Motion Using a Data Table and Corresponding Graph

Both Logger *Pro* and LabQuest App make it easy for students to examine data in both table and graph forms, enabling them to explore the relationships between the two representations of the data. Figure 5 shows the connection between the table values and the graph for the selected portion of the position-time behavior of an object undergoing simple harmonic motion.

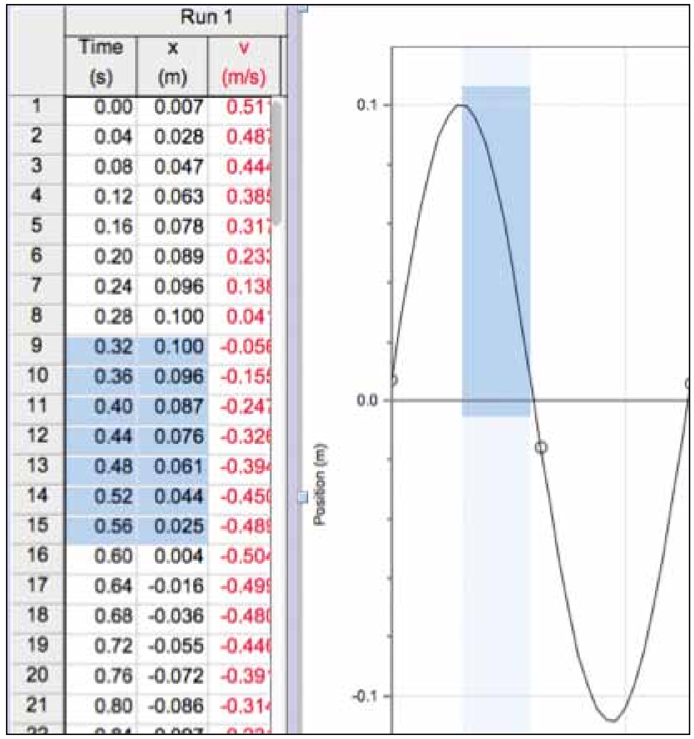


Figure 5. Table and Graph

Support for Other Practice 4 Goals

Vernier probeware can also be used to provide an instructional environment where students meaningfully engage with data in activities related to the other goals listed above associated with Practice 4.

- Logger *Pro* software and LabQuest App promote the formulation and testing of hypotheses by allowing students to make predictions before they actually perform the experiment—supporting these goals for Practice 4:
  - *Analyze data systematically, either to look for salient patterns or to test whether the data are consistent with an initial hypothesis.*
  - *Recognize when the data are in conflict with expectations and consider what revisions in the initial model are needed.*
- The graphing and statistical tools in Logger *Pro* and LabQuest App allow students to evaluate the strength of their conclusions—supporting the following goal of Practice 4:
  - *Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.*
- Within the Vernier lab books, questions in the Extension sections of the experiments encourage students to perform additional investigations—supporting yet another goal of Practice 4:
  - *Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.*

Examples of these ways of using the Vernier probeware are provided below, based on activities from Vernier lab books.

INSTRUCTIONAL EXAMPLE

Use of Vernier Probeware to Support Data Analysis re: Hypothesis Testing and Model Revision

A typical naive conception held by students in a chemistry class is that the graph of pressure versus volume of a gas looks like the one in Figure 6. However, when they perform the experiment with a Gas Pressure Sensor connected to a syringe, they find that the graph actually looks like that in Figure 7.

These data show that the plot of an inverse relationship $(P \propto {}^{1}\!/_{V})\,(P \propto {}^{1}\!/_{V})$ is a hyperbola rather than a line with negative slope.

The "Boyle's Law" experiment in the *Chemistry with Vernier* lab book provides students an opportunity to further revise the model by suggesting that the volume readings need to be adjusted from the scale readings on the syringe to account for the extra volume of gas between the syringe and the actual sensor. The software allows students to easily create a new calculated column of values (adjusted volume) and display a plot of pressure versus adjusted volume that is a better fit (Figure 8).

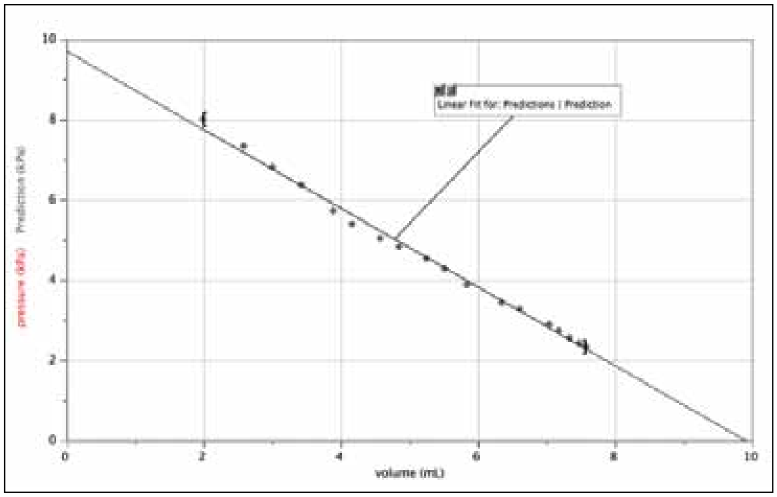


Figure 6. Prediction

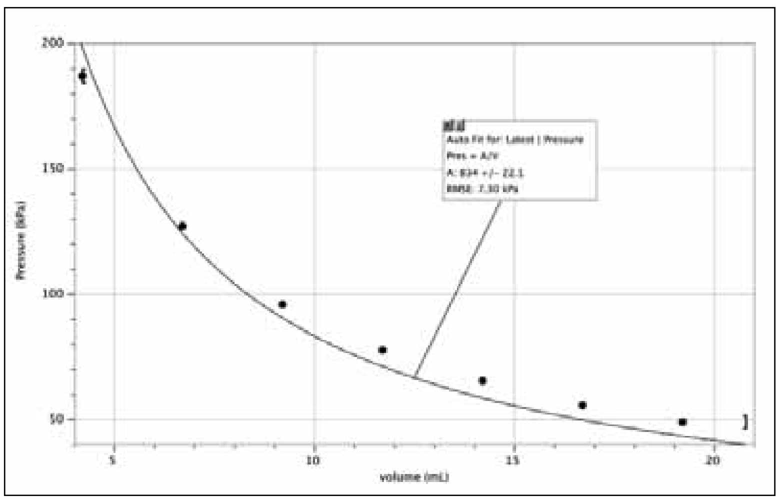


Figure 7. Experimental Data

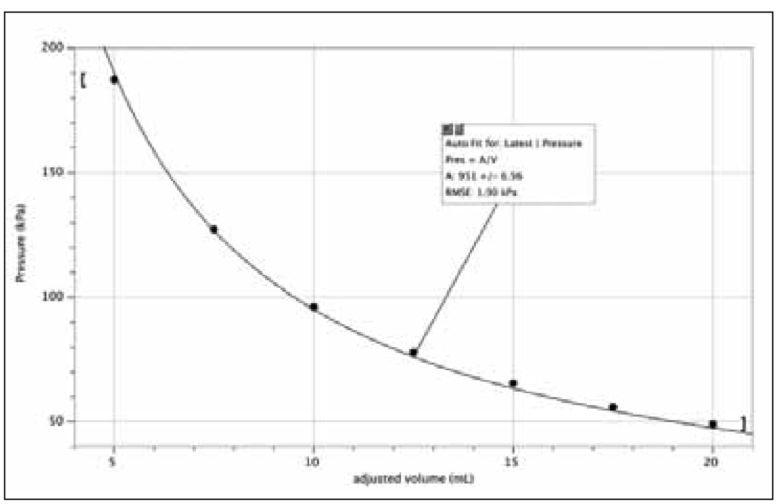


Figure 8. Adjusted Volume

INSTRUCTIONAL EXAMPLE

Use of Vernier Probeware to Support Data Evaluation

In the “Enzyme Activity” experiment from *Advanced Biology with Vernier*, students readily conclude that the rate of enzyme activity is related to the enzyme concentration in the sample. But they can show more specifically that the enzyme activity is proportional to the concentration by a closer examination of the graph of rate versus number of drops, as shown in Figure 9.

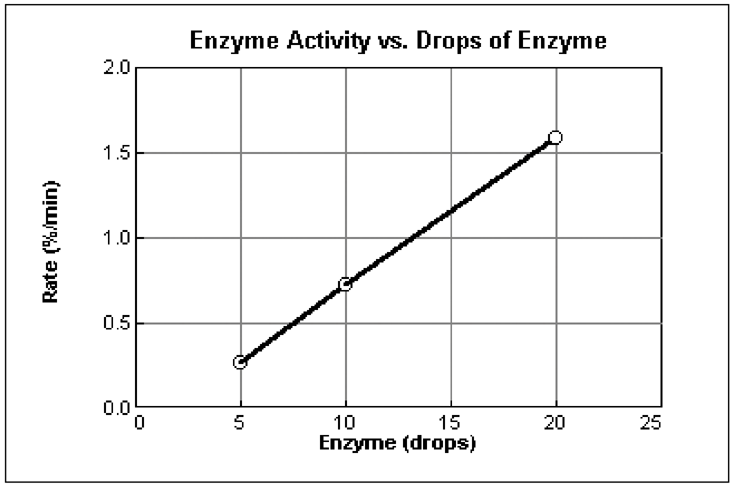


Figure 9. Effect of Concentration

INSTRUCTIONAL EXAMPLE

Use of Vernier Probeware to Support Additional Investigations

To the right are two examples from the Extension sections in the Vernier lab books that show how students are prompted to conduct additional investigations.

In the "Relative Humidity" experiment in *Middle School Science with Vernier*, students are prompted: "Compare relative humidity values at sunny and shaded sites outdoors."

In the "Newton's Second Law" experiment in *Advanced Physics with Vernier*, students are asked: "Suppose that you had kept the net force acting on the cart the same, but varied the mass instead. Predict the shape of the graph of acceleration *vs.* mass. Your answer to the question above should suggest why it would be very difficult to perform an experiment to test your prediction. Explain."

Familiarity with Standard Techniques

Describing the necessary progression across grade levels of skills and knowledge associated with analyzing and interpreting data (Practice 4), the *Framework* states:

> In middle school, students should have opportunities to learn standard techniques for displaying, analyzing, and interpreting data; such techniques include different types of graphs, the identification of outliers in the data set, and averaging to reduce the effects of measurement error. Students should also be asked to explain why these techniques are needed.
>
> As students progress through various science classes in high school and their investigations become more complex, they need to develop skill in additional techniques for displaying and analyzing data, such as x-y scatterplots or cross-tabulations to express the relationship between two variables. Students should be helped to recognize that they may need to explore more than one way to display their data in order to identify and present significant features. They also need opportunities to use mathematics and statistics to analyze features of data such as covariation. Also at the high school level, students should have the opportunity to use a greater diversity of samples of scientific data and to use computers or other digital tools to support this kind of analysis. (pp. 3–12)

Use of the Vernier probeware, software, and instructional resources supports student development of familiarity with standard techniques in a variety of ways. For example:

- *Middle School Science with Vernier* provides students with data tables to record values from sensors or from measurements they make with conventional devices (e.g., rulers, balances). Some of these require students to average values obtained from multiple trials. This gives the instructor opportunities to discuss how to treat measurement errors. Students are then instructed to use the analysis software to generate the kind of graph (line or bar) best suited to interpreting the data.
- Logger *Pro* provides a variety of features that allow students to examine their data from multiple perspectives. For example, students can view data in multiple formats; zoom in on relevant sections of a graph; produce and analyze video; and incorporate data from multiple sources on one graph. For illustrations of these uses, see the instructional examples provided on the following pages.

INSTRUCTIONAL EXAMPLE

Using Vernier Probeware to Examine Data in Multiple Ways

The Vernier software allows students to examine data in a variety of ways while familiarizing themselves with standard scientific techniques. Some of the most powerful of these are illustrated to the right.

Presenting the same data in multiple ways. In this example from *Chemistry with Vernier*, students initially consider the plot of pH versus volume of titrant in an acid base titration (Figure 10). They are then guided to view a plot of the first derivative of pH (Figure 11). Because the rate of change of pH is greatest at the equivalence point, viewing this second graph can help students more precisely locate the endpoint of the titration.

Similarly, while a plot of penny mass versus year the penny was minted (Figure 12) reveals that pennies fall into two different types, a histogram plotted in Logger *Pro* (Figure 13) allows students to more clearly see the distribution of masses for each group.

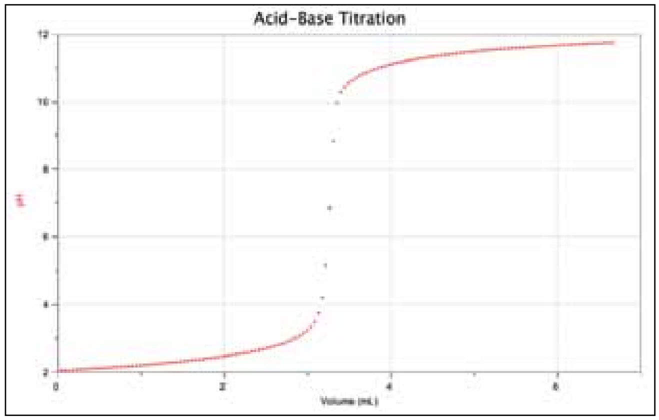


Figure 10.
pH vs. Volume of Titrant

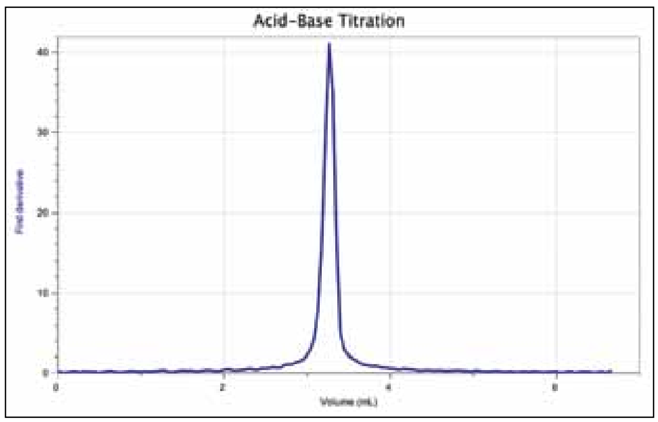


Figure 11.
First Derivative of pH vs. Volume

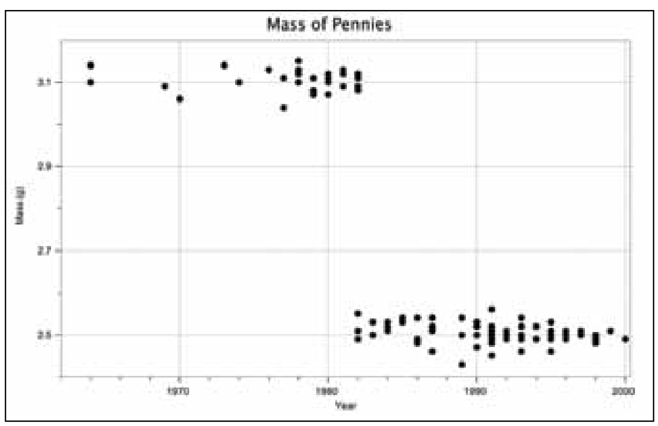


Figure 12.
Mass vs. Year Minted

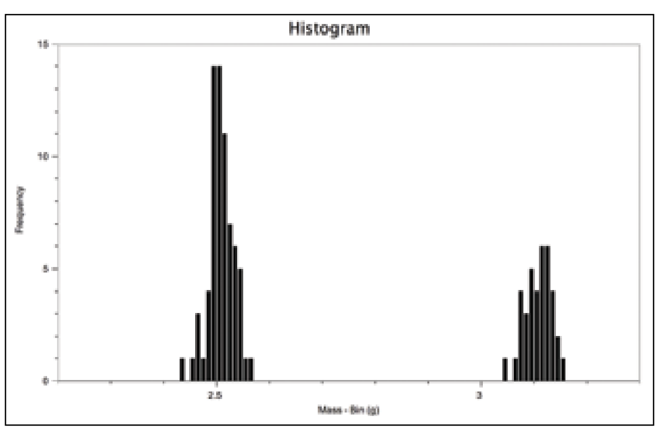


Figure 13.
Frequency vs. Mass

Zooming in. The data analysis software allows students to zoom in on a particular portion of a graph. This allows them to observe features that may not have been visible at first, as shown in the example below, where the additional details in Figure 15 allow students to fit a curve to the salient portion of the data.

Video analysis. Using the video analysis feature in Logger *Pro*, students can produce and analyze position-time and velocity-time graphs describing the motion of an object captured in a movie file. Furthermore, they can produce an animated display that uses vectors to represent the velocity of the moving object (Figure 16).

Data from multiple sources on one graph. An example from a salinity experiment in *Environmental Science with Vernier* shows that by displaying plots from various sites on the same graph, students can conclude that cyclic trends in salinity also depend on location (Figure 17).

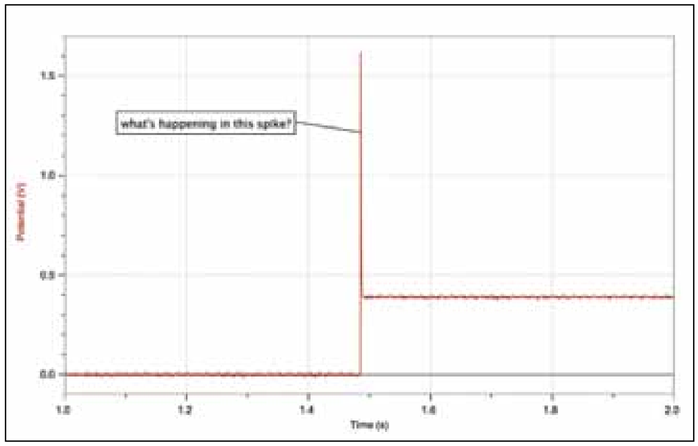


Figure 14. Potential vs. Time

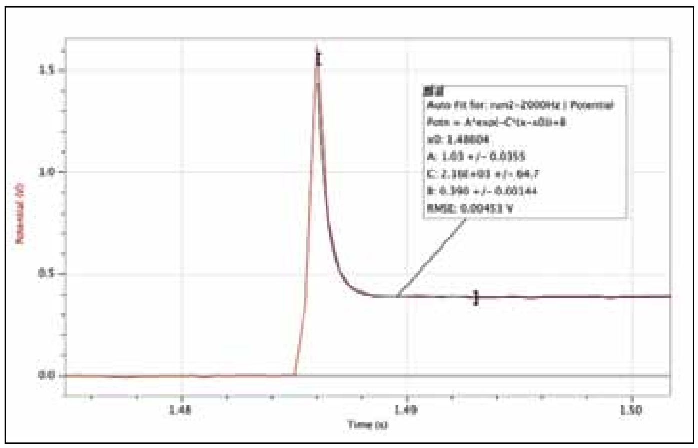


Figure 15. Close-up of Spike from Figure 14

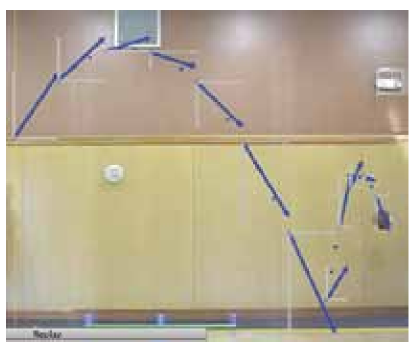


Figure 16. Vectors Representing Velocity of a Basketball

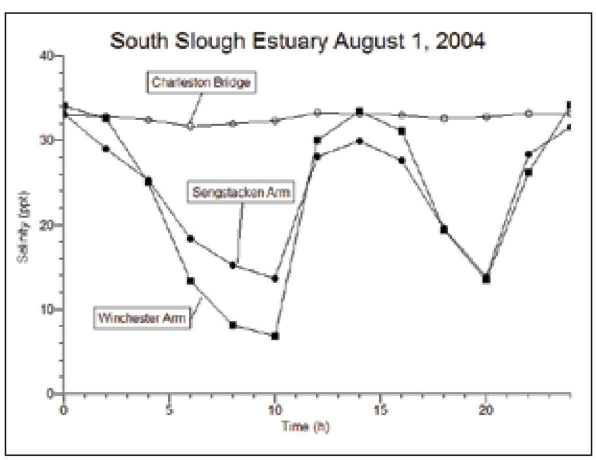


Figure 17. Salinity vs. Time

Practice 5. Using Mathematics, Information and Computer Technology, and Computational Thinking

Vernier probeware, used in ways specified in the Vernier lab books, provides substantive support for three of the five Practice 5 goals specified in the *Framework*:[6]

- "Recognize dimensional quantities and use appropriate units in scientific applications of mathematical formulas and graphs.
- "Express relationships and quantities in appropriate mathematical or algorithmic forms for scientific modeling and investigations...
- "Use grade-level appropriate understanding of mathematics and statistics in analyzing data." (pp. 3–14)

Specific instructional examples are provided below.

[6] The other two goals relate to mathematical modeling of computer simulations and testing mathematical expressions, computer programs, and simulations against real-world outcomes—areas that lie mostly outside the focus of Vernier's probeware offerings.

INSTRUCTIONAL EXAMPLE

Use of Appropriate Units and Expressions of Relationships to Facilitate Scientific Modeling

Logger *Pro* software and LabQuest App include the capability for students to perform a curve fit to non-linear data, as shown in Figure 18. Additionally, in some cases the lab activities direct students to modify a variable so as to produce a graph that can be described by a *linear* relationship (Figure 19).

This process, called linearization, is described in detail in three tutorial files that come with Logger *Pro* software. Linearization has the advantage of displaying the units for the slope and y-intercept of the best-fit line. More than just a constant of proportionality, the slope is usually related to a system parameter. In the case above, the units of the slope,

$$\frac{\mathrm{J}}{\mathrm{m}^2/\mathrm{s}^2}$$

simplify to kg, the unit for mass. Upon closer inspection, students can see that the value of the slope is approximately half of the system mass, leading them to derive the expression for kinetic energy:

$$E_k = 1/2\, m v^2$$

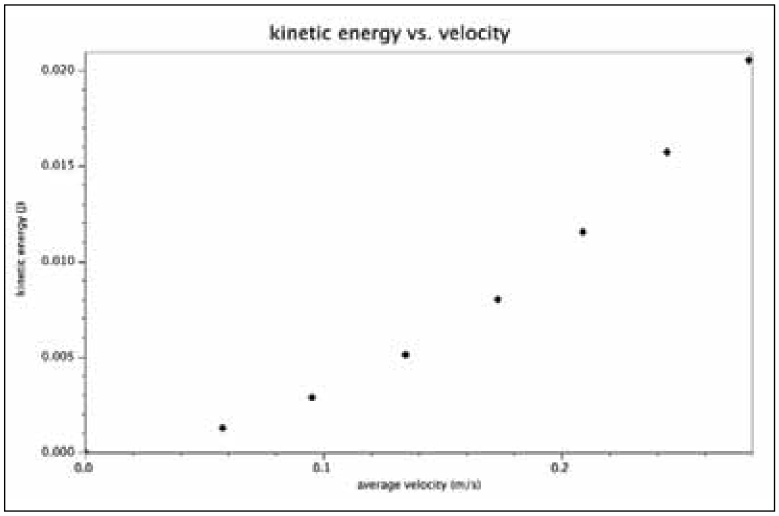


Figure 18. Original Non-Linear Graph

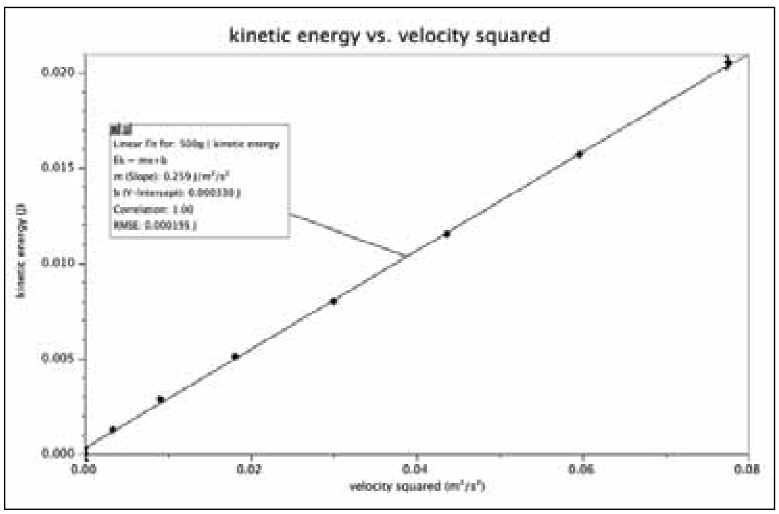


Figure 19. Linearized Graph

INSTRUCTIONAL EXAMPLE

Grade-Appropriate Use of Mathematics and Statistics to Analyze Data

Analyses of data called for in the experiments in the Vernier lab books are appropriate to the audience for which the books are written. See examples to the right.

Students in middle school may be asked to average the values of the distance a "crash test dummy" was thrown from multiple collisions to plot against the velocity.
Students in a high school physical science course might use the statistics feature of Logger *Pro* software or LabQuest App to determine minimum and maximum values of temperature during a neutralization reaction.
High school chemistry students might use the interpolation feature of Logger *Pro* software or LabQuest App to determine the concentration of an unknown solution from its absorbance value in a Beer's law plot or the intersection of best-fit lines applied to different regions of a cooling curve to determine the freezing point depression for a solution.
Students in high school or college physics might use the parameters of a sine fit to data to determine the frequency of oscillatory phenomena.
Students in a college-level physics course might be directed to use Logger *Pro*'s ability to find the area under a P-V graph to determine the net work done during a thermodynamic cycle.

Specific Recommended Technology Experiences

Describing specific technology-related skills students should develop in connection with Practice 5, the *Framework* states:

> Students should gain experience in using computers to record measurements taken with computer-connected probes or instruments, thereby recognizing how this process allows multiple measurements to be made rapidly and recurrently. Likewise, students should gain experience in using computer programs to transform their data between various tabular and graphical forms, thereby aiding in the identification of patterns. (pp. 3–14)

All of the capabilities described above are supported by the Vernier probeware and associated software. In particular, the ability to switch between tabular and graphical representations helps students understand the connection between the representations. For example, when a graph reveals that a linear relationship exists between variables (like that between position and time for an object moving at constant speed), an examination of the data table will show nearly constant differences between values of position for equal time intervals, as shown in Figure 20.

		Vide
	Time (s)	position (m)
1	0.0667	1.1
2	0.267	1.0
3	0.467	0.94
4	0.667	0.89
5	0.933	0.82
6	1.20	0.75
7	1.47	0.67
8	1.73	0.59
9	2.00	0.52

Figure 20. Position vs. Time

The *Framework* also calls for instruction to "introduce [students] to the use of mathematical relationships to build simple computer models, using appropriate supporting programs or information technology tools" (pp. 3–14). A strength of Logger *Pro* is that it lets students model mathematical relationships—without reference to any specific collected data—by selecting from a variety of built-in functions and studying how changing the parameters changes the shape of the graph.

Practice 8. Obtaining, Evaluating, and Communicating Information

Used in appropriate instructional contexts, Vernier probeware provides substantive practice for students with all four goals related to this practice specified in the *Framework* as tasks students should be able to carry out by grade 12:

- "Use words, tables, diagrams, and graphs (whether in hard copy or electronic), as well as mathematical expressions, to communicate their understanding or to ask questions about a system under study.
- "Read scientific and engineering text, including tables, diagrams, and graphs, commensurate with their scientific knowledge and explain the key ideas being communicated.
- "Recognize the major features of scientific and engineering writing and speaking and be able to produce written and illustrated text or oral presentations that communicate their own ideas and accomplishments.
- "Engage in a critical reading of primary scientific literature (adapted for classroom use) or of media reports of science and discuss the validity and reliability of the data, hypotheses, and conclusions." (pp. 3–20)

More specifically:

- The Vernier data-collection software and the activities in the lab books directly involve students in using words, tables, diagrams, graphs, and mathematical expressions to communicate their understanding about systems under study—supporting the first goal listed above. A particular strength of the Vernier products is that they help students connect their understanding of these various representations.
- The opportunities students have to interpret the data and graphs resulting from their own experiments help to prepare them to critically evaluate representations of data in texts or other sources, including those found on the web—thus supporting the second goal listed above.
- In the *Investigating Biology through Inquiry* and *Investigating Chemistry through Inquiry* books by Vernier, students are encouraged to choose researchable questions related to a particular investigation and are expected to present their research results to the class using graphs, tables and charts—thus supporting the third goal listed above.
- In *Investigating Chemistry through Inquiry*, students consult external resources as part of their process.

Conclusion

Research supports the instructional value of having students use technology tools such as those provided by Vernier probeware—featuring a wide variety of probes combined with powerful software—for data collection, analysis, and visualization. Results from the National Assessment of Educational Progress and other sources suggest that use of such technology tools can contribute to higher student test scores in science and deeper understanding of science concepts, particularly when probeware is used to support scientific investigations carried out by students.

The potential value of probeware in science education is attested by guidelines and requirements from influential national organizations and state standards, many of which either specifically recommend probeware use or describe use of technology tools in ways that align well with probeware capabilities. Additionally, Vernier probeware, software, and related instructional resources support student investigations that can provide experiences with core scientific practices, as called for in *A Framework for K–12 Science Education*.

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Appendix: NAEP 2009 Data Analysis Procedure

Researchers from IESD carried out the following steps on January 11, 2012 to analyze data that is available for 2009 Science from the National Center for Education Statistics at http://nces.ed.gov/nationsreportcard/naepdata/, obtaining results cited earlier in this paper.

1. Select Main NDE (Data Explore for Main NAEP)
2. Select Criteria
   a. Subject: Science
   b. Grade: Grade 12
   c. Framework: Science 2009
   d. Category: NAEP Scale Scores; Sub Category: Science Scales; Measure: Overall science scale
   e. Jurisdiction: Nation public
   f. Click Select Variables button (bottom right)
3. Select Variables
   a. Expand Instructional Content and Practice
   b. Expand Models of instruction/classr...activities
   c. Select Use computers for science
   d. Click Edit Reports button (bottom right)
4. Edit Reports
   a. Verify criteria and variables
   b. Click Build Reports button (bottom right)
5. Build Reports
   a. Click Significance Test
   b. For Items 1-3, keep defaults
   c. For Item 4, select Show score details
   d. For Item 5, under Variable, select Use computers for science
   e. Click Done button (bottom right)
   f. Click Export Reports (near top right)
   g. Select Report 1 and desired file format