Probeware:
A Definition[1]

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Probeware Defined

Probeware refers to educational hardware and software used for real-time data acquisition, display, and analysis with a computer or calculator. Probeware is also known as microcomputer-based labs or MBL. When used with a calculator, it is known as Calculator Based Labs or CBL.

By connecting probes to a computer running suitable software, students can observe data displayed in a variety of formats as it is being collected. When used in an inquiry-based learning context, this capacity can significantly increase and speed learning. Probeware has been used widely in science, mathematics, and technology education.

The probeware hardware consists of probes that use sensors to convert some physical property into an electrical signal. The electrical signal from a sensor usually requires some form of interface electronics to put it into a form that can be read by computers. Over 40 kinds of probes are used in education, although temperature, light, and distance probes are most common.

Software used with probes can usually represent the data from the probe as a number, dial, or graph. There is great educational value in having students see the display change in "real time", that is as soon as the physical input changes. In this way, learners quickly associate the physical change with the way the representation changes. Some software can also be used to analyze the data as soon as it has been collected. For instance, the user may want to fit data to a function or filter out noise.

Probeware software frequently also includes support for probe calibration. The software uses a calibration equation to relate the "raw" values it reads from the sensor to a physical value such as temperature reported as degrees Celsius. The process of calibration adjusts this equation to increase its accuracy. This is necessary because not all sensors are identical and most actually change their sensitivity, or "drift," over time. Inexpensive sensors, which are frequently found in education, are more likely to drift. Calibration generally involves placing the probe at several known values of the physical property that the probe measures. For instance, a temperature probe might be placed in freezing and boiling water because those temperatures are known.

Educational Values

The use of probeware in education has been hindered by misunderstandings of its appropriate educational role. The most common misconception is that probeware can harm student learning by reducing the amount of exposure to hands-on learning. As with any technology, probeware can be used well or poorly, but with appropriate instructional design, probeware actually increases student learning from inquiry. Quality use is not, however, an automatic consequence of using probeware, good instructional strategies and designs are necessary. Good approaches that use probeware still leave it to the student to decide what to measure and how to interpret the results. Frequently, the role of the probeware is to lessen the drudgery, allow students to focus more on the experiment, and increase the amount and range of experimentation students can undertake.

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Another misconception about probeware is that it is an incomprehensible “Black Box.” There is no way, the argument goes, that students can possibly understand everything that is happening in an experiment that uses probeware, so how can they believe the results or learn from them? The combination of sensor, electronics, computer, software, and even the monitor, is a black box that students should not even try to understand. The point is, however, that for students to use probes effectively, all they need is to understand the relationship between input and output; it is educationally sound to treat everything between as a black box. They can learn quickly, for instance, that an increase of temperature at the sensor causes the line to go up on a graph on the display. They do not need to know how the display works to use this representation for exploration and learning.

An Example: The Cooling Curve Experiment

The cooling curve experiment that was first demonstrated in 1978, illustrates how probeware can improve student learning by reducing the amount of clerical work required and increasing student interaction with the experiment and reflection about the results.

The experiment involves a substance like mothballs that melts between room temperature and 100°C. A sample of the warm liquid substance is placed in a test tube that is immersed in water that is cooler than the melting temperature. As the liquid cools its temperature drops quickly to the melting temperature and then stays constant—plateaus—until all the liquid turns to solid. Then it continues cooling. This experiment is important because it illustrates that heat and temperature are different; at the plateau, heat is being extracted but the temperature remains constant because the latent heat of solidification provides the heat transferred to the surrounding liquid.

Using a thermometer to measure the temperature of the mothballs, students typically take an entire lab to gather the temperature data of a single cooling experiment. They must plot the data later, often days later. They often fail to understand the connection between features on the graph and the properties of the substance that is cooling. Having never seen a normal cooling curve, they often fail to understand that the plateau observed during a liquid-solid transition is special. Consequently, the key observation that the plateau represents the evolution of latent heat, is completely missed.

Because the temperature sensor can be tiny and respond quickly, the sample can be smaller when probeware is used. This means that one cooling experiment can be completed in a few minutes. There is ample time to do a normal cooling curve without a phase change and then compare that to a curve with a phase change. Furthermore, students can see the temperature graph evolving as the experiment is underway. They see the solid start to appear as lovely snow-like particles at the beginning of the plateau and complete solidification at the end of the plateau. They can speculate about the reasons for the temperature being constant while the experiment is underway. If they are lucky, they can also observe supercooling. A second sensor can be used to measure the temperature of the surrounding water to verify that it was cooler and extracting heat, although the temperature of the mothballs remains constant.

The Ultrasonic Motion Detector

One of the most important probeware developments occurred at TERC in 1983. During a sabbatical year at TERC on leave from his physics teaching at Whitman College, Jim Pengra first connected an ultrasonic camera focusing module to a computer to measure distance continuously. The interfaced module generates an ultrasonic pulse and then measures the time until its first echo. The computer can convert that time into the distance to the nearest object in front of the module. The module can make these measurements 20 or more times per second, giving very detailed data about the distance to a moving object. The computer can calculate the object’s velocity from the change in distance, and acceleration from the change in velocity. Any of these quantities can be plotted in real time.

A student moving in front of the ultrasonic detector can see a graph of his or her position, velocity, or acceleration against time. Students as young as fourth grade can learn to interpret these graphs in very little time. Ron Thorton has studied high school and college student learning of the relationship between these three quantities. He consistently finds substantial gains in student understanding that are greater than any combination of lecture, problems, and traditional labs.

New Directions

Probeware continues to be refined, gaining increased flexibility while becoming less expensive. One important current development has been the use of probeware with calculators and handheld computers. This not only reduces the cost of the computer, it makes it feasible to extend experiments outside the lab and classroom.

Current developments in probeware are also expanding the ways data can get from sensors into computers. Smart probes contain a microprocessor that converts the sensor signal directly into a computer-readable format that can be plugged directly into a computer. They use standard serial inputs, USB, or computer-specific ports. Our laboratory is are experimenting with wireless probes that communicate over infrared or microwaves as well as sensors that connect directly to the Internet and can be read anywhere there is an Internet connection.

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