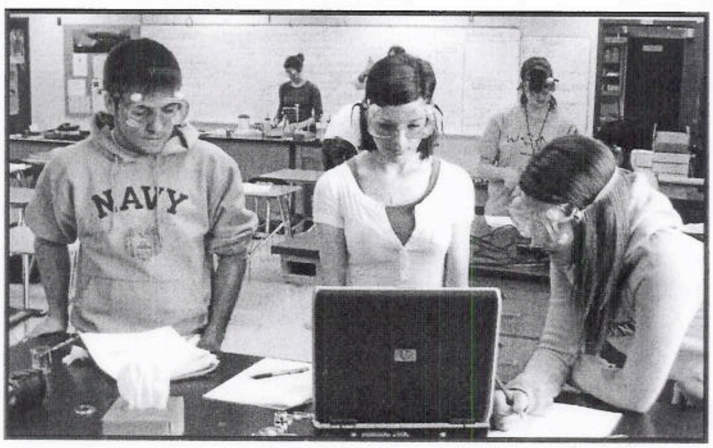
Technology Enhances CHEMISTRY LABS

By Gene Wicks, MACUL Grant Recipient

Since 1992, I have taught general chemistry students at both the high school and university levels. Since I have worked with hundreds of struggling chemistry students, I understand how important it is to illustrate abstract chemical concepts with carefully constructed laboratory activities. My earlier success with technology enhanced physics labs encouraged me to consider trying technology enhanced chemistry labs. With this in mind, MACUL funding, and laptops from Michigan's Freedom to Learn Project, I introduced several new labs into my Advanced Placement (AP) Chemistry course. My intent was to use technology to help students better understand chemical titrations, reaction rates, activation energies, equilibrium reactions, slightly soluble substances, and the graphs associated with these concepts.



Standards Met

In this project, laptop computers, Vernier LabPros, and chemistry sensors are used to promote guided inquiry learning. In inquiry learning, students ask questions, formulate hypotheses, predict outcomes, perform tests, analyze results, and draw conclusions that may lead to additional questions. Guided inquiry ensures that students are properly trained to safely perform new lab operations and competently use lab equipment unfamiliar to them. Inquiry learning is supported by both the Michigan Science High School Content Expectations and the National Science Education Standards.

Lab Activities

On our laptop computers, a software program called Logger Pro controls the Vernier LabPros, which are microcomputer data-collection devices. The LabPros are, in turn, connected to chemistry sensors measuring quantities like pH, volume of solution added, or absorption of light, which is proportional to the concentration of a substance dissolved in a solution. This setup allows students to rapidly collect high quality data, which can be readily graphed and analyzed on the laptops during our 60-minute lab periods. Thus, students spend more time during class focusing on scientific principles rather than tedious procedural details. For many students, this makes the labs more fun and the chemistry concepts easier to remember. If experimental difficulties are encountered, this setup also gives us the ability to quickly recognize and correct them.

Utilizing data-collection technology, my AP Chemistry students performed the following laboratory activities. These activities were adapted from Advanced Chemistry with Vernier; Experiments for AP, IB, and College General Chemistry (Randall et al., 2007).

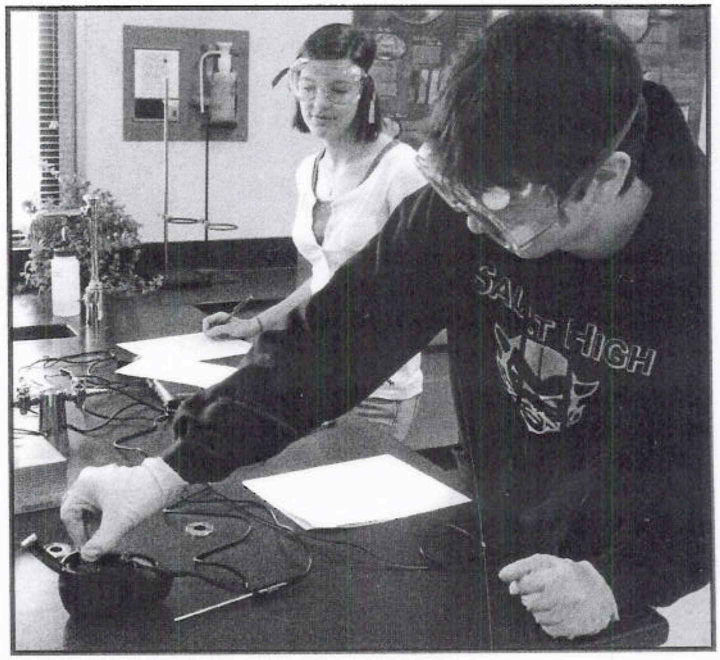
(1) Acid-Base Titration. First, students performed manual strong acid-strong base titrations by adding a standardized sodium hydroxide, NaOH, solution to a known volume of hydrochloric acid, HCl, solution using a buret and an indicator. The goal was to determine the unknown concentration of the hydrochloric acid. Afterward, they repeated the titrations using technology. They used a pH probe to follow the progress of each titration and a drop counter to electronically measure the volume of NaOH solution added. The equivalence point, at which moles of acid and base are equal, was determined on a laptop computer by viewing the second derivative graph of pH versus milliliters of NaOH added. Similarly, students performed weak acid-strong base titrations by adding a standardized sodium hydroxide, NaOH, solution to a known volume of acetic acid, HC2H3O2. Afterward, they analyzed the titration graphs to help determine the unknown concentration of acetic acid.

(2) Rate Determination and Activation Energy. Students reacted solutions of crystal violet with sodium hydroxide, NaOH, at four different temperatures while using a colorimeter to measure the effect of temperature on the reaction rate. Afterward, they plotted the natural logarithm of the rate constants, ln k, versus the reciprocal

of the corresponding Kelvin temperatures, 1/T, to help determine the activation energy, Ea, for the reaction.

(3) Determination of an Equilibrium Constant. First, students used a colorimeter to determine absorbance for five standard $FeSCN^{2+}$ solutions having known concentrations at room temperature. Next, they created a "standard curve" by plotting absorbance against concentration for the five standard solutions. Afterward, they used their standard curve to find the unknown concentration of a different $FeSCN^{2+}$ solution. Finally, the concentrations of Fe^{3+}, SCN^{-}, and $FeSCN^{2+}$ were determined under equilibrium conditions and the equilibrium constant, Keq, was calculated.

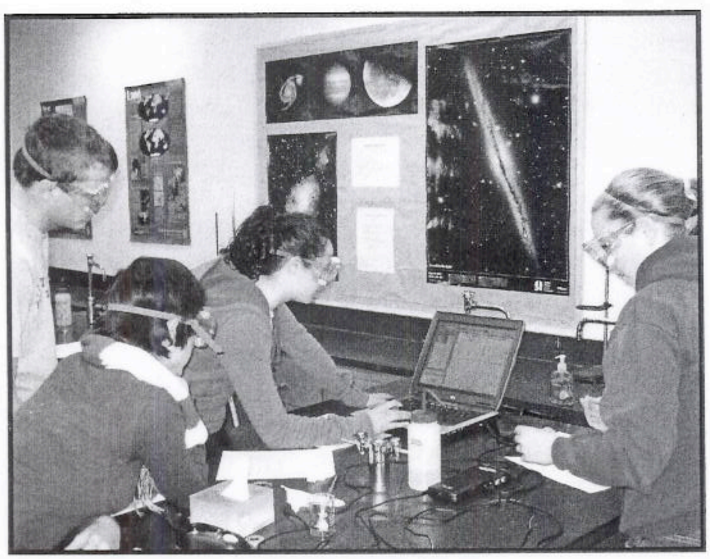
(4) Determining the Solubility Product Constant, Ksp, of Calcium Hydroxide. Students titrated a saturated calcium hydroxide, $Ca(OH)_2$, solution with a standard hydrochloric acid, HCl, solution monitoring the reaction progress with a pH sensor. Afterward, they determined the hydroxide ion concentration for the saturated calcium hydroxide solution and calculated its solubility product constant, Ksp, from the results.



Evaluation and Sharing

Student learning was assessed by a pre-evaluation/post-evaluation strategy for the chemistry activities described. The evaluation for each activity was composed of four to five questions that could be assessed as completely correct or incorrect. This promoted rapid compilation of the results. When scores for the pre- and post-evaluations were compared, the average percent improvement in student learning was obtained. The learning gains for each lab activity were 64% for Acid-Base Titration, 58% for Rate Determination and Activation Energy, 70% for Determination of an Equilibrium Constant, and 18% for Determining the Solubility Product Constant of Calcium Hydroxide. The average learning gain for all activities was 53%.

At the end of the school year, the students completed a written evaluation for the lab activities. When asked if the technology enhanced chemistry labs helped them to learn and understand AP Chemistry better, most of the respondents said yes with a few of them indicating that the graphs were particularly helpful. Several students indicated that they especially enjoyed the Acid-Base Titration lab because they took time to compare and contrast manual titrations, involving indicators and burets, with technology enhanced titrations, involving pH probes and electronic drop counters. Although a few students mentioned that they found the technology confusing at first, the most common complaint was the time constraints under which they worked. Due to equipment considerations, safety concerns, and the complexity of selected lab operations, our chemistry labs generally required two or three days, and at times, it was challenging to reach a suitable stopping point within a 60-minute class period. Many students suggested that two-hour class periods would be helpful in the future.



The lab activities and preliminary evaluation results were shared with my coworkers during an April Science Department meeting. The project was also presented to the school board in May and to regional science teachers attending the Eastern Upper Peninsula Fall Educators Conference in October, 2009.

Conclusion

During the past four years, I have adapted more than thirty technology-based, guided-inquiry lab activities to the needs of my physics, AP Physics, and AP Chemistry students. After an initial adjustment period, most students have responded well to the technology enhanced labs I have introduced. In general, data-collection technology helps to promote student-centered learning and science as inquiry. From an educator's perspective, it fosters a learning environment that includes reflection, application, exploration, and synthesis of concepts. From a student's perspective, it quickly produces high quality data that supports key scientific principles. It also gives students a chance to use technology skills in high school that most believe will be important in their college experience and future workplace.

Reference

Randall, J., Vonderbrink, S. A., Volz, D., Holmquist, D., Gastineau, J., & Dodd, G. (2007). Advanced Chemistry with Vernier; Experiments for AP, IB, and College General Chemistry (2nd ed.). Beaverton, OR: Vernier Software & Technology.

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