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# InterChemNet: Integrating Instrumentation, Management, and Assessment in the General Chemistry Laboratory Course

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The InterChemNet (ICN) project offers a Web-based platform to support instrumentation, curriculum delivery, and evaluation of the effectiveness of laboratory curricula. ICN was conceived to overcome barriers to active learning in large general chemistry classes by targeting the lab portion of the course. Historically, University of Maine general chemistry labs had about 550 students all doing the same procedure in a given week. While this approach was efficient as far as preparation and grading was concerned, it hardly inspired a sense of curiosity in students *(1, 2)* and did not convey much to students about how scientists do science. By contrast, highly individualized lab sessions have been proven *(3, 4)* to be effective in helping students construct their own learning but at a high cost in resources and teacher time. In this context, ICN began in 1993 to change the environment for hands-on and active learning in the laboratory program and to provide tools to manage individualized student learning experiences. Although this is the first comprehensive article describing InterChemNet, a number of presentations describing the evolution of ICN have been given at national educational forums *(5–9).*

## Individualizing Labs with Modern Instrumentation

ICN began with the belief that students in introductory science courses should have hands-on experience with modern chemical instrumentation *(3, 10–18).* This kind of laboratory experience is valuable because it illustrates the principles of the science while exposing students to modern practice, using instruments comparable to those found in a research or medical analytical laboratory. Thus, the initial goal of ICN was to offer full spectrum instruments, such as a Beckman UV–vis diode array spectrometer, to large numbers of students in general chemistry.

The ICN development team overcame two major barriers to providing large-scale access to instrumentation. The first barrier involved the economics of introducing relatively expensive equipment to our largest courses. We overcame this barrier by creating a Web-based computer infrastructure to maximize the ratio of students to instruments.[1] Second, our students encountered an ease-of-use barrier when trying to use the powerful yet non-standard software packages provided by instrument makers. Our response was to create an instrument interface suitable for an educational setting.

Students use valuable instrument time only to scan samples, taking about 1 minute per spectrum to acquire and store needed data. The shifting of data analysis from scarce instrument consoles to ubiquitous PCs results in a dramatic increase in the efficiency of instrument use;[2] this allows us to serve the needs of 550 students each week (~90 students per lab period) with four UV–visible instruments[3] and four FTIR machines.[4] We estimate that each technique costs between \$2 and \$10 (in 2003 dollars) per student credit hour to implement and maintain.[5] The system is easily scalable so that larger or smaller programs can purchase and use more or fewer instruments. Existing instruments can be integrated into the system with the addition of a short control program. We note that the ICN approach is slightly different from some other networked instrument systems[6,7] although over time some of these differences have diminished.

Since every student's full spectrum scans (whether UV–vis or IR) are unique and are securely stored for later use, data analysis can be performed on any computer that can connect to the server via the Internet to retrieve the data. Students use an account name and password to access the spectral data through the Web browser, and a uniform interface makes it easy for students to display, analyze and print their data. It is important to stress that ICN uses a number of real instruments in much the same way that practicing chemists now use multiple techniques to analyze their samples. Figure 1 shows the Web-based data analysis screen for a UV–visible experiment. The spectral analysis interface mimics many of the features of commercially available programs. However, the interface that we have constructed is much simpler than that provided by the instrument makers. It is our experience that the simplification of the data screens helps focus the students' attention on the data that the technique provides rather than on figuring out the "system". Thus the interface for FTIR data is quite similar to that for UV–vis experiments. Perhaps most important from a pedagogical

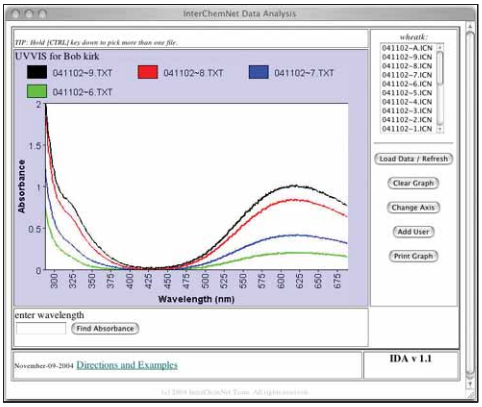



Figure 1. Students use an account name and password to access their spectral data through a Web browser. A uniform interface makes it easy for students to display, analyze, and print their data.

point of view is the ability for several students to display their own spectra simultaneously on one screen. This feature allows students to collaborate on group projects.

By 1998, over 2000 students had used UV–vis and FTIR spectrometers with InterChemNet *(19),* and the hardware and software infrastructures for managing very large streams of student-generated data efficiently and economically were in place. From a course management perspective, the generation and handling of large amounts of individual data demonstrated to us that we could provide a more individualized experience even for large courses. We realized that the same technology could be used to address other important problems in the general chemistry lab program, including course management and curriculum development, and evaluation.

### *Lab Management*

The ICN program has powerful functionality that allows a user to set up a course as well as monitor multiple sections within a course. These features are accessed through an Administrator Progress Page and can be used to build a course by selecting the sequence and availability of experiments. A key innovation is the ability to offer multiple experiments during a given lab period. Lab handouts, assignments, and quizzes can be entered and edited in a series of linked pages. The administrator establishes the number of sections and the lab instructor associated with each section. The lab manager or instructor can also control the times at which various curricular resources are made available online to students. For example, a given lab can be restricted to weeks 4 and 5 of the course. Since multiple labs also can increase the number of different chemicals and supplies needed in a given week, the lab manager also has a tool to track inventory and plan quantities of chemicals needed based on the student selections from the available choices.[8] Since the system was designed for large courses with multiple sections taught by different teaching assistants or lab instructors, administrators can also view and modify any information within a particular section, including student progress, assignments, grades, and evaluation question results.[9]

A password-protected Instructor Page allows lab instructors to monitor the progress of students in their lab section(s). Instructors can view the individual progress page of any student in their sections by accessing the student progress page directly, thus viewing the assignments and status of each student. Instructors also have access to the results of evaluation data and can assign or edit grades and comments on each experiment. The grades are posted instantaneously on the student's progress page. Thus, the ICN system provides an effective means for communication between instructors and students.

### *Student Centered Activities: Individualized Pathways*

In contrast to the lockstep approach that was in use previously at the University of Maine, the ICN system allows students to dynamically create their own individualized pathways through the course. The term *individualized pathways* is our metaphor for a range of strategies that can be implemented to individualize every student's experience. These strategies can include presenting different procedures and treatments of the handout to different groups of students, providing students a choice of laboratory experiments, and generating different assignments within a given lab procedure. The latter two strategies are obvious to a student (e.g., choice of two different experiments in a given week) and have the effect of enabling students to have some control over their lab experience. The first strategy mentioned above is among those aimed at curriculum development and assessment (e.g., differences in experimental procedures). Thus, individualized pathways are meant, in the short term, to generate enthusiasm for lab, while, in the long term, to provide a means to improve the curriculum.

At the beginning of the semester, each student creates an account name and password to access her own personal progress page. Figure 2 shows a student progress page with several choices for a particular week. Within a given time period, different labs will typically relate to the same concepts and technical skills although they will be contextualized in different ways for different potential audiences (e.g., nursing students, engineers, environmental science students). Going one step further, ICN allows the creation of variable sets within a given lab procedure. For example, a lab involving

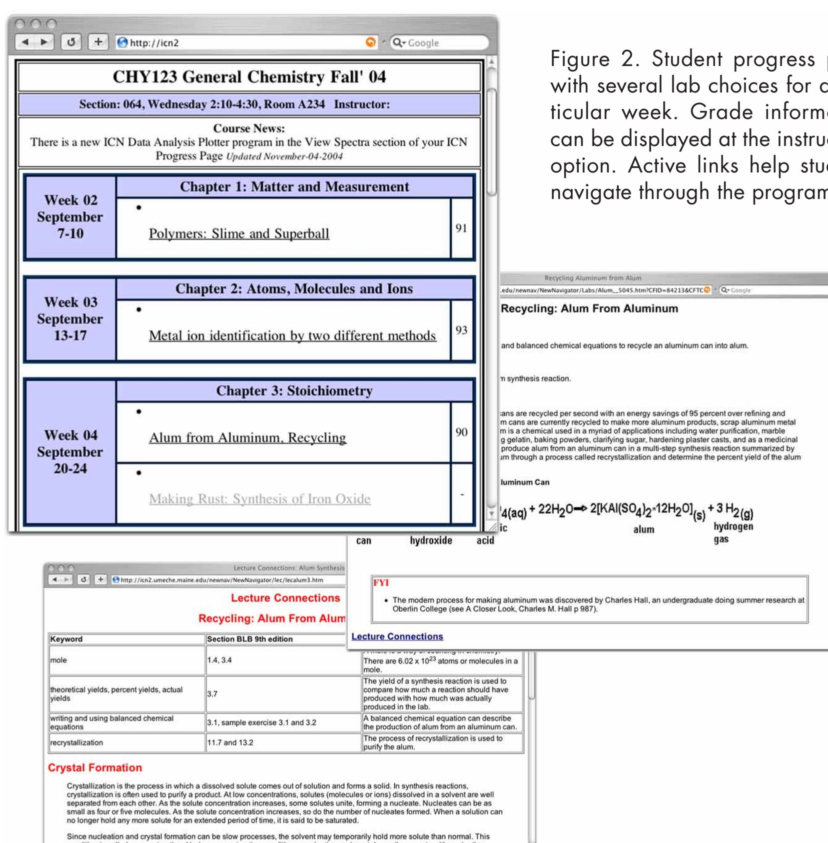



Figure 2. Student progress page with several lab choices for a particular week. Grade information can be displayed at the instructor's option. Active links help students navigate through the program.

the titration of a weak acid can be created with three or four different weak acid compounds each of which may be prepared at different initial concentrations. Thus within a lab section of twenty students, even if eight students have chosen the same lab, their individual assignments will be different and will generate different and unique data sets. This allows the ICN approach to promote student interaction and collaboration while providing a check on outright copying. Students can then access their individualized handout on the Web along with links to Material Safety Data Sheets, video clips of procedures, pictures of lab equipment, references to sections in the lecture text, and background information pertinent to each experiment.

### *Integrated Assessment and Evaluation Tools*

The InterChemNet system has an integrated evaluation module that tracks student learning and attitudes as they use the system. The questions are created along with the curriculum materials and are designed to be part of the sequence of materials viewed by the students as they progress through the course. For example, the instructor can insert a series of online questions that must be answered before the student can gain access to the following week's lab assignment. One built-in option allows for a sequence of pre- and post-testing for each experiment. In the "Administrator" and "Instructor" pages, the evaluation module delivers preformatted graphical summaries of the students' responses to the evaluation questions. Thus evaluation results from different courses and/or multiple sections of the same course can be compared quickly and easily.

Three types of questions are currently being used in the ICN system: multiple choice, number input, and text response. Questions have been categorized as either science-content or attitude questions. Students answer content questions before they receive the lab assignment but receive no answers or feedback for these questions. After the assignment, they again answer the same questions and receive feedback and the correct answer if appropriate. The evaluation questions are not graded but must be completed in order to receive the next assignment and progress through the course. The answers to the multiple choice questions are collected in the database and can be treated in a statistical manner as described below to provide a quick snapshot of student performance and satisfaction. The number input and text response questions allow for the collection of open-ended responses and are thus less amenable to automated data treatment. These responses are more helpful for understanding how students are thinking. We note, however, that careful reading and coding of these responses permits a statistical treatment of this data as well.

Once students have completed an experiment and answered the accompanying evaluation questions, the ICN database contains a rather rich store of data about student performance. In principle these data could be mined for correlations between student performance and a whole host of factors such as major, gender, instructor. ICN provides a very rapid assessment of student performance in order to get an ongoing sense of what is working and where problems have arisen. The evaluation module provides this rapid screening of data in two ways. First, it provides an automatic analysis of pre- and post- testing results for each experiment and includes a graphical display of those results. Second, the evaluation module can display the text of open-ended response questions to the instructor for a rapid scan of student answers to these questions. This has been used to identify points that need to be clarified in the next class or changes that might result in better learning.

**Table 1. Results from Students' Evaluation Responses to the Laboratory Course and ICN Program**

| Course Context | Evaluation Questions ($n$ = Respondents) | Response Scale (%) Ranging from 4, Most Favorable, to 1, Least Favorable | | | |
|---|---|---|---|---|---|
| | | 4 | 3 | 2 | 1 |
| Week 5: Precipitation | How fair are the grading procedures?[a] ($n$ = 90) | 42 | 57 | 0 | 1 |
| Week 7: Acid–Base Titation | Did the experiment provide insights into the chemical technique or concepts?[b] ($n$ = 158) | 25 | 63 | 9 | 3 |
| Weeks 11–12: FTIR Absorption of Greenhouse Gases | Did the experiment provide insights into the chemical technique or concepts?[b] ($n$ = 391) | 13 | 56 | 25 | 6 |
| Week 13: Gas Laws | What is your overall rating of the CHY 123 Lab Course?[c] ($n$ = 160) | 22 | 58 | 18 | 2 |
| Week 13: Gas Laws | What is your overall rating of the Web-based handouts and other lab course materials?[d] ($n$ = 160) | 21 | 64 | 13 | 2 |

[a](Very fair/Reasonably fair/Not very fair/Unfair); [b](Many insights/Some insights/Few insights/No insights); [c](Excellent/Good/Fair/Poor); [d](Excellent/Usually good/Need improvement/Poor)

## Results

The full ICN system was student tested in Fall 2001, when 500 students taking CHY 123 (Introduction to Chemistry Laboratory) used ICN to perform 5,000 individually assigned experiments and take approximately 10,000 spectra using 4 UV–visible and 4 FTIR spectrometers. Students accessed the Web-based program more than 25,000 times during the semester. Online evaluation questions were used to monitor student attitudes toward the laboratory course as a whole and to using ICN in particular.

Sixty students provided comments (in Fall 2001) that expressed an overall approval of the new laboratory program, particularly with the ability to choose experiments each week. Some of these comments were as follows:

> "The way the lab is run is awesome. Working at your own pace allows you to learn and absorb more info."

> "I found it helpful that students were able to choose which labs they were going to do. It allowed us to integrate the labs with the lectures."

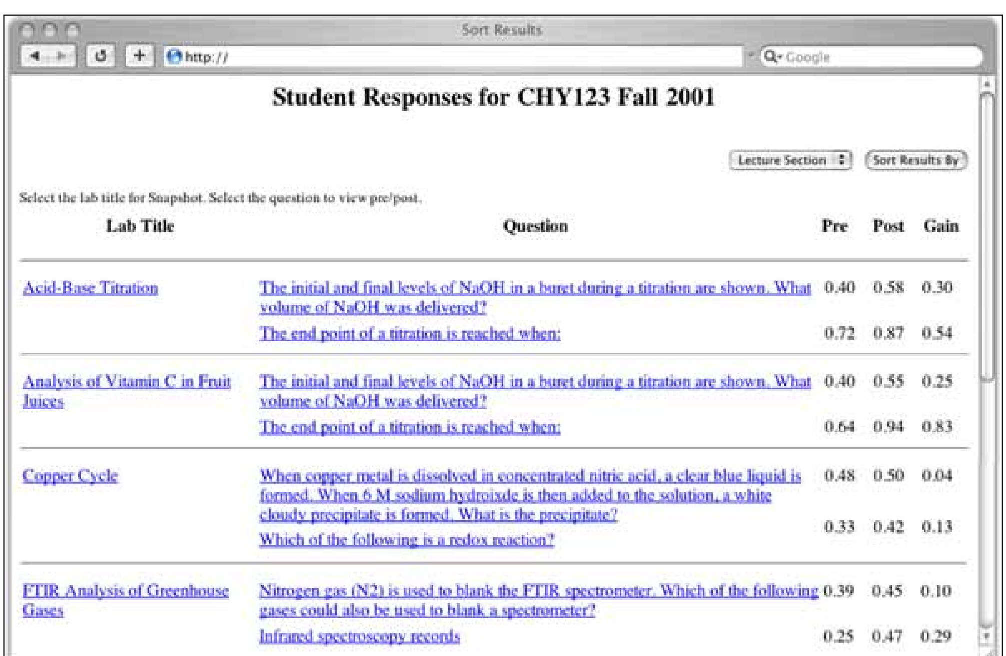
In addition to this anecdotal evidence gathered at the end of the semester, Table 1 shows a sampling of qualitative evaluation data taken during the course. We note that these questions were all created by the course administrator and can be easily changed. Results from qualitative questions such as those shown in Table 1 relating to grading procedures, general insights into chemical techniques or concepts, or overall ratings of the course or course materials are provided to instructors immediately and can be used for guidance in course modifications.

In addition to monitoring student attitudes about specific experiments and the course, the ICN program can also be used to evaluate specific learning outcomes associated with each experiment. Figure 3 shows summary data (generated automatically by the ICN program) for four experiments offered in the fall of 2001. The questions shown here (e.g., multiple choice) lend themselves to quantitative measures of student learning. We have implemented a "gain" index *(20, 21)* as shown below,

$$\text{gain} = \frac{\text{postscore (\%)} - \text{prescore (\%)}}{100\% - \text{prescore (\%)}} \tag{1}$$

to provide a rapid comparison of the effectiveness of multiple experiments in a course. The first two experiments displayed in Figure 3 were offered during the fourth week of lab and were intended as alternative treatments of the same set of techniques and concepts.

The first experiment, a conventional analysis titled Acid-Base Titration, was selected by 208 students; the second experiment, Analysis of Vitamin C in Fruit Juices, was chosen by 337 students. Each student who selected one of these two experiments was randomly assigned a "pre" question and a different "post" question. We focus here on the query, "The endpoint of a titration is reached when:" which was presented to 106 students in the first lab (60 "pre" and 46 "post") and 167 students doing the second lab (85 "pre" and 82 "post"). The group of students who completed Acid-Base Titration demonstrated a gain for this question of 0.54, while those who did Analysis of Vitamin C in Fruit Juices posted a gain of 0.83. Assuming that both groups of students are drawn from the same population, we have calculated that the probability that the difference in these two gains is random is less than 0.01; this result was obtained using a two-tailed *t*-test with pooled variance *(22).* The difference in gains may be due to the superiority of one set of curricular materials over the other and a result like this leads us to look carefully at



Student Responses for CHY123 Fall 2001

Select the lab title for Snapshot. Select the question to view pre/post.

| Lab Title | Question | Pre | Post | Gain |
|---|---|---|---|---|
| Acid-Base Titration | The initial and final levels of NaOH in a buret during a titration are shown. What volume of NaOH was delivered? | 0.40 | 0.58 | 0.30 |
| | The end point of a titration is reached when: | 0.72 | 0.87 | 0.54 |
| Analysis of Vitamin C in Fruit Juices | The initial and final levels of NaOH in a buret during a titration are shown. What volume of NaOH was delivered? | 0.40 | 0.55 | 0.25 |
| | The end point of a titration is reached when: | 0.64 | 0.94 | 0.83 |
| Copper Cycle | When copper metal is dissolved in concentrated nitric acid, a clear blue liquid is formed. When 6 M sodium hydroixde is then added to the solution, a white cloudy precipitate is formed. What is the precipitate? | 0.48 | 0.50 | 0.04 |
| | Which of the following is a redox reaction? | 0.33 | 0.42 | 0.13 |
| FTIR Analysis of Greenhouse Gases | Nitrogen gas (N2) is used to blank the FTIR spectrometer. Which of the following gases could also be used to blank a spectrometer? | 0.39 | 0.45 | 0.10 |
| | Infrared spectroscopy records | 0.25 | 0.47 | 0.29 |

Figure 3. Screenshot showing an Administrator view that summarizes online evaluation questions for a series of laboratory experiments.

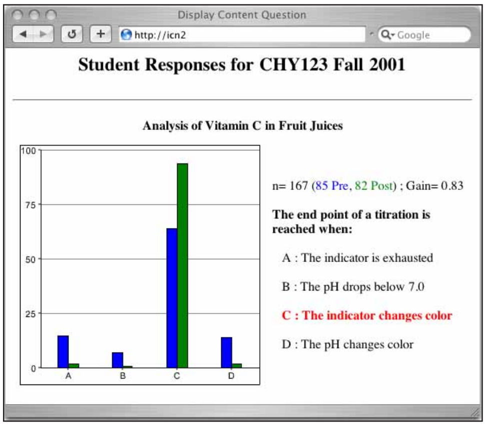



Figure 4. Graphical display of results of the online pre- and post-lab questions exploring student understanding of the endpoint of a titration. The *y*-axis gives frequency of response as a percent of total.

both procedures for clues. However, lab choice is one of the very interventions we are trying to assess and this may affect our assumptions about the randomness of the population. We hope to construct, in the future, a more nuanced picture of the learning dynamics in the general chemistry lab, correlating such factors as learning style preferences *(23)* and gender differences with lab selection, as well as learning results; these results will be reported in a future communication.

For a more detailed look at a specific experiment, the ICN program can generate a display like that of Figure 4, which shows the complete pre- and post- results for the "endpoint" question for the vitamin C lab. This graphical display is useful for visually oriented instructors and provides a more complete picture of the alternative answers and the evolution of the distribution of those answers, pre- and post-. The rather high performance on this question is typical of questions focused on specific experimental techniques.

However, not all of the data indicate that students are learning what *we think* the experiment should be teaching. For example, as Figure 3 shows, in an experiment called Copper Chemistry: The Copper Cycle, the first question asks about the nature of the precipitate formed when sodium hydroxide is added to aqueous copper(II) nitrate. Our outcome data shows that 48% of the students responded correctly before the experiment and only 50% responded correctly after conducting the experiment; this suggests that our lab module did not meet our curriculum goals. We welcome such data as a signal that we should focus our attention at a point that we had not recognized as problematic. Since the ICN evaluation module allows us to gather evaluation data throughout the semester as part of the course delivery mechanism, we hope that it will dramatically lower the activation barrier for conducting and analyzing chemical education research within a course.

## Discussion

As the ICN team achieved its goal of providing access to modern instrumentation, we became intrigued by the possibility of adding additional features including:

- Offering students choice of lab experiments without increasing the time commitment of the lab manager
- Creating individual lab assignments to promote student collaboration (but not copying)
- Developing a standardized way to create lab experiments
- Defining and offering a course simultaneously with other courses
- Integrating assessment into the delivery of the course

### *Engaging Students in Learning Chemistry*

One of the goals of the ICN project was to develop a curriculum that leads students from mastery of basic skills and concepts to more open-ended "discovery" labs. By carefully introducing new tools such as spectrometers early in the course, more complex, integrative exercises using an array of chemical tools are possible later in the course. A side benefit is the ability to offer instruments for use in upper level courses and for research at times when the large courses do not meet.

Central to our conception of individualized pathways is the possibility of student choice of experiments based on factors such as personal interest, disciplinary (major) focus, and level of difficulty. Our expectation, borne out by student feedback, was that choice would provide more active engagement with the material through conscious selection of experiments as opposed to the passive completion of mandatory assignments. Students must use the system to access and analyze their data, especially spectral data, and to answer questions about the lab. InterChemNet's Web-based format is conducive to embedding ancillary information: students have access to a wealth of information regarding lab procedures, safety, and calculations. A notable feature is a Lecture Connections module that correlates chemical concepts used in lab experiments with source material in the lecture course and textbook. Evaluation data shows that students find this feature helpful for integrating the lecture and laboratory portions of the course.

One striking consequence of making possible individualized student pathways has been a concomitant change in the role of the lab instructor (teaching assistant) from authority and disciplinarian to resource person. With ICN, the instructor acts as a source of information about techniques and principles rather than acting as the source of "correct procedure" for the whole section. Likewise, our teaching assistants are instructed to encourage collaboration between students to learn techniques and to do data analysis while their differing assignments render moot the problem of copying of results. TA training, which is always a critical aspect of running a large lab program, now requires a change of emphasis from mastery of specific content to be conveyed to students to the principles of guiding students through the process of doing science. This aspect remains an active area of development in our chemistry program.

### *Dissemination and Outreach*

The ICN system has been developed and extensively tested at the University of Maine. We should stress that we have taken considerable care to make the system easy for instructors to use to modify experiments or add new ones. It is a system for course development and evaluation not just curriculum delivery. The program code relies on a dynamic relational database structure using industry standard Access database and Cold Fusion server development tools.[10] Instead of a series of static Web pages, the ICN system offers a Web interface to modify the content of the database. This data is then incorporated into Web pages that are served out to student "clients".

By using industry standard software tools, the system is portable for users—both students and teachers—and reasonably straightforward to install for administrators. Students can access the client side of the program from any computer cluster or dorm room that is connected to the Internet. Instructors from college or even high school settings can create and modify a course using standard Web browsers. Most science departments, colleges or high schools have an IT department or guru to set up standard Web services.

The services provided by ICN can be used at a variety of institutions with different curricular goals. A good contrast with the large general chemistry program at the University of Maine is the adoption of the system at Bangor High School to provide access to spectroscopy experiments *(24)* to students in tenth and eleventh grades. In this collaboration with M. Benoit, a Chemistry department "loaner" UV-vis spectrometer[11] and the ICN program were used for data acquisition and analysis with modified labs and new curriculum materials *(25)*. The ICN system was also used to acquire data on student learning in the high school classes. The adaptation has proved so successful that Benoit sought and was awarded a Toyota Tapestry grant[12] for the school to obtain instruments and is now assisting in the training of other high school teachers.

Potential adopters of ICN may first be interested in managing the use of spectrometers or perhaps in the possibility of creating individualized pathways for their students. The system can also be used simply to do online evaluation of an existing curriculum; here, at Maine, for example, we have used the ICN program to perform an evaluation of our ongoing Peer Led Team Learning project *(26)* associated with the General Chemistry lecture course. In any case, it is easy to start from the existing curriculum and gradually phase in the use of desired features. Some users (particularly at high schools) may wish to adopt—with only minor modifications—some of the 40 or so experiments that have been integrated into the working system here at the University of Maine. The capabilities of ICN offer the opportunity to define local curricular goals, and to deliver and assess a course to meet those goals. An eventual outcome of a successful dissemination project is the creation of a mechanism (e.g., a database) for sharing curricular innovations, integrated lab experiments, and evaluation strategies with other users of the system. InterChemNet provides a common framework to help manage the complex task of comparing learning outcomes in different learning environments.

### *Curriculum Development Cycle and Action Research*

InterChemNet's integrated evaluation module provides instructors an easy method to query their students on a host of issues. The instructor can control the mode of questioning and the content in such a way as to strike the desired balance between assessment, evaluation, and promotion of critical engagement with the lab data for analysis. The resulting data need to be collated and presented in a systematic fashion. ICN contains an integrated analysis tool in order to perform rapid and automated statistical treatment and display of the datasets generated by each curricular unit; examples of these results are presented in Figures 3 and 4. The evaluation can be carried out simultaneously at several different "curricular scales". At the coarsest level, ICN can automate pre- and post- testing of the entire course and display gains in student learning immediately. But the real strength of the system lies in the ability to go to finer levels, evaluating individual lab experiments (e.g., Figure 4) or even the learning of a given concept within a lab. This approach allows the instructor to assess how particular curricular "interventions" have worked.

The integrated assessment tools have allowed us to confirm, in some cases, the efficacy of our curriculum innovations *(27)*. Just as interesting, and probably more important, are the cases where rapid assessment indicates low or nonexistent gains—as with the copper chemistry lab mentioned above—or where students express dissatisfaction with aspects of the course. The immediate feedback allows for rapid modification of the learning materials and course protocols followed by further evaluation, in some cases, before the end of the course. This curriculum development cycle is similar in many ways to the action research methodology *(28)*, and is consistent with a growing trend in chemical education towards this type of research study *(29)*. The deep integration of assessment with curriculum delivery, made possible by the ICN approach, should dramatically reduce the overhead associated with conducting pedagogical research in a working classroom. For more information, visit the Web site at *http://www.interchemnet.com*.

## Acknowledgments

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## Notes

1. Although some industrial companies in the mid-1990s were developing spectra-based management programs for their scientists, we were interested in a program appropriate for an educational setting, that is, easy for introductory students to use without sacrificing any of the essentials of instrumental use.

2. In stand-alone mode, where a spectroscopic instrument and its console are used to acquire and then analyze data—mimicking the mode of use in research—every student might need about 30 minutes to complete this portion of an assignment. At the University of Maine, with 120 students to be served in a 3-h period each afternoon, this would require about 20 machines of each type to be available, ignoring, of course, the tendency for students to finish prep work in bunches. Taking this latter effect into account, 40 machines might be needed for a program such as ours. Indeed, this

paradigm of instrument use is similar to that applied to inexpensive equipment like pH meters and to a lesser extent, single wavelength spectrometers like the SPEC20. For spectrometers costing between \$2,000 and \$10,000, this mode of use is not economically viable.

3. Beckman DU 7500 full spectrum UV–visible scanning spectrometers from Beckman Coulter Corporation are used.

4. Midac M Series FTIR spectrometers from Midac Corporation are used.

5. At current prices, a suitable FTIR machine or a high-end UV–visible spectrometer would cost about \$10,000. Counting 5% for maintenance and repairs, such a machine lasting for about seven years would have an overall cost of \$13,500. In this same seven-year period this instrument is used by one-fourth of the student population, or about 1365 students. Thus, one such instrument costs about \$10 per credit hour. For a less expensive UV–visible spectrometer costing about \$2000, a similar analysis leads to an estimate of \$2 per student credit hour.

6. Systems that integrate instrumentation for the education market include Acculabs Products Group, Casio EA-100, Microlab, PASCO Scientific, MeasureNet Technology, SCI Technology (Labworks), TAL Technologies, Team Labs, Texas Instruments, and Vernier Software and Technology.

7. Systems that focus on analog-to-digital conversion for research and industry with uses in education include DATAQ Instruments, Keithley Instruments, Labtronics Inc., and National Instruments: see *http://www.umsl.edu/~chemist/books/compute/interfac.html* (accessed Nov 2005).

8. The inventory tool tracks the number of students selecting particular experiments. This can be viewed by experiment or by section and used by the lab manager to estimate the amount of chemicals needed for each lab section, for each day, or for the entire week depending on how the lab experiment prep is done.

9. Other course infrastructure software that integrates evaluation with delivery includes Blackboard, WebCT, and WebAssign: see *http://www.umsl.edu/~chemist/cgi-test/mysoft.pl?category=9* (accessed Nov 2005). ICN has specific features designed for use in laboratory courses.

10. Access is a Microsoft database product. Cold Fusion from Macromedia uses SQL query protocol to insert database information dynamically into Web pages served out to clients.

11. Ocean Optics Chem-2000 UV–visible spectrometers from Ocean Optics, Incorporated were used.

12. Toyota Tapestry grants are awarded through the National Science Teachers Association: *http://www.nsta.org/* (accessed Nov 2005).

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