Student Projects

TITLE: Bringing "C.S.I." to the LAB: Investigating Arson Using GC-MS Analysis of Accelerants
by Adam Boyd '05
Adviser: Randy Larsen

The project takes on the task of writing and developing a failsafe case study laboratory experiment. Students are presented with a problem in the form of a story and are tasked with developing methodology for solving the problem. Emphasis is on developing analytical thinking, students taking ownership, and making connections with the real world. Students are presented with an arson mystery and must determine the innocence or guilt of a suspect, based on chemical analysis. Their task is to develop a procedure to test for presence of accelerants in ash "recovered from the scene of the crime" in order to determine whether arson was involved and who might be responsible.

TITLE: Coordination Compounds of 2,5-bis(4'-tert-butylpyridinium-1'-yl)-3,6-dioxy-1,4-benzoquinone
by Tabitha Clem '05
Adviser: Andrew Koch

This project is technically inorganic chemistry, though Professor Koch is an organic chemist. The project takes an organic compound that Koch made several years ago and binds it to metals. Because the organic compound is very electron-withdrawing, it can stabilize metals having unusually low charges (especially +1). This project also builds on a previous student's work: Kristina Borstnik '99 worked with the same organic compounds and tried binding them to cobalt. Her results were so interesting that they became the starting point, more or less, for this SMP. This project is considered inorganic chemistry rather than organometallic chemistry because there are no carbon-metal bonds—the organic compound binds to the metal through oxygen, not carbon.

Student Research

Cocaine Research Stimulates Students

by Wrenn Heisler '99, Editor of River Gazette

"Of course, just the word 'cocaine' is an attention-grabber—as Larsen says, there is a 'certain mystique' about working with an illegal substance."

Left: Randy Larsen works with Sandy Zieman '06 on cocaine data analysis.
Right: Zach Ernst '05, overall task leader, prepares cocaine extraction for analysis.

Walking into chemistry professor Randy Larsen's "Quant. Lab," what one sees is anything but the formulaic, scripted environment that defines many undergraduate chemistry laboratory courses. The quantitative analysis class, otherwise known as Chemistry 305, is an upper-division chemistry course in which students study varying methods of measurement and analysis. Though that may not sound too exciting, this lab is a very lively environment, and seems to be, essentially, driven by student inquiry, rather than a previously laid-out laboratory experiment. The lab teems with conversation—students talk excitedly about what they're doing, eager to share the processes of their project. Frankly, it is hard to believe the room is occupied by only eight students!

Professor Larsen is experimenting with a new way to teach quantitative analysis—through cocaine! In their lab, the class has been working on a case study project that tests and quantifies amounts of cocaine found on a variety of international currency. Of course, just the word "cocaine" is an attention-grabber—as Larsen says, there is a "certain mystique" about working with an illegal substance. But since the levels of cocaine that can be detected are only nanograms, there is certainly no danger to students in working with the currency.

What is refreshing for students is that they are working with something that has a real-world application, rather than the classic lab experiment that gives students a white powder and asks them to analyze what it contains. In the classic experiment, the professor already knows the answer. What is remarkable about what Larsen is doing with his class is that he is running an undergraduate lab that has no pre-established results. It is real-life research.

The project itself is termed a "case study" approach, which is geared toward allowing students a concrete application for their investigation as well as developing analytical thinking skills. Though these would seem to be obvious goals of the undergraduate laboratory, most traditional experiments focus solely on the measurement skill and the equipment knowledge that is attained through the experiment. The case study approach does both, rather than just emphasizing "memorization and recapitulation of facts," according to Adam Boyd '05. It presents students with a realistic problem and asks them to find answers to questions based on the information and tools that they have available to them.

In this particular case study, produced by Ed Acheson of Millikin University in Illinois, the questions focus on whether cocaine levels vary with the denomination of the currency, with the location where the currency was printed, or with the geographic location where the currency was collected. Students are also asked to examine whether there is a correlation between the age of the bills and the cocaine levels.

Larsen first decided to do this case study as a method of bringing "some reality to what we do" in undergraduate chemistry. When he sent out an all-staff e-mail last summer to solicit currency for the experiment, the response was amazing. He expected to have minimal response, but ended up with over 120 currency samples from over 20 countries. The students, too, were amazed with the response, and at the beginning of the project, were a little overwhelmed with the amount of work ahead of them. Randall Reif '06 says he thought the project would be "Really, really hard" at first, and the quantity of bills overwhelmed him at the beginning. As they moved on through the project, however, students began feeling a sense of ownership—just what Larsen wanted. Students were less concerned with the *amount* of work they were doing and were more focused on the interesting subject matter and the amount of control needed to make the project a success.

The project requires students to use gas chromatography/mass spectrometry technology and other advanced analytical tools in addition to maintaining an up-to-date database on the cocaine measurements they were tracking. Larsen appoints an overall group leader to manage the task, a quality assurance manager, and a security control manager in order to make sure the currency is not lost or stolen. Students take a lot of pride in their control over the project. Students this fall even set up a relationship with a computer science course to post the results of the study to the Web.

These students are not only studying the interesting relationship between cocaine use and currency circulation, but also learning lifelong skills. "The skills we're learning here we really will use later," Randall Reif said. As Larson says, he is "not trying to get them to know what [he] already developed," but come to their own conclusions and develop procedures that work for the experiment.

Larsen reflects that one of the most challenging parts of the cocaine case study from a teaching perspective is working as a team with students. He feels as if he has more of a "Junior Partner and Senior Partner" relationship with students than a student/teacher relationship. Sandy Zieman said that Larsen is "less like a teacher and more like a mentor" after her experience working on the cocaine case study with him. She is hoping he will be the adviser for her St. Mary's Project next year. Randall Reif is grateful for the peer relationship the class formed with Larsen. "He treats us like adults," Reif said, thankful for being given the autonomy and ownership the lab permits.

Atomic Physics Dives Deep

by Wrenn Heisler '99, Editor of River Gazette

"You normally think about lasers heating things—with the Bond movies and everything—but these lasers are really neat. [They] are cooling things down."

Phil Ramon '06 and Chuck Adler work on the Magneto-Optic Trap being used to trap and cool rubidium atoms for use in a new United States Navy gyroscope. Students travel to Pax River Naval Air Station two to three times a week to work on this atomic physics research with Associate Professor Chuck Adler, Adjunct Professor Frank Narducci, and Justin Nash '01.

Junior and senior physics students are diving into an opportunity to do hands-on research for the Navy. A unique partnership has been set up by SMCM physics professor Charles "Chuck" Adler and Frank Narducci, who is not only a physicist at Patuxent River Naval Air Station (NAVAIR) but also an adjunct professor with the physics department at St. Mary's. This new relationship makes it possible for students to work on atomic physics research aimed at developing more stable gyroscopes for Navy submarines. These gyroscopes, created through the isolation and cooling of rubidium atoms via a Magneto-Optic trap, would enable Navy subs to have more stable navigation systems. The "gyroscope really is for long-term, GPS free navigation," according to Narducci.

The partnership between St. Mary's and NAVAIR was set up to be mutually beneficial. St. Mary's students get the opportunity to do real research that is being used for very important developments—they are completing research on this task for their senior-year St. Mary's Projects—and the Navy gets researchers.

Students are helping the Navy to develop several components of a larger effort to improve long-term navigation. The first is the Magneto-Optic trap, which places a small amount of the rubidium metal into a vacuum chamber and then directs lasers into that chamber. The six lasers push on the atoms from different directions and are able to quickly isolate and cool five to six billion atoms down to a millionth of a degree above absolute zero, where all motion stops. These isolated atoms (see cover photo) will later be used to create the gyroscope that will make a more stable navigation system for the Navy.

The Magneto-Optic trap is set up on a big table on which many pieces of glass and plastic are mounted. Through these, lasers are directed into a large, metal vacuum chamber. It looks like a labyrinth for lasers, and that's essentially what it is. "You normally think about lasers heating things—with the Bond movies and everything—but these lasers are really neat. These lasers are cooling things down," Adler explains. The lasers have to be directed in such a way that they have the power needed to trap and cool the rubidium atoms.

Students are also working on the construction of a large-scale atom trap on their own—from scratch. They are developing the electrics, the lasers, and the trap itself. Adler is very excited about this project and hopes it will increase atomic physics capability at the College. "The lasers that Frank is using for controlling the model here cost about $10,000 apiece, so it's much cheaper for us to build them. Plus, there's a design that a colleague of mine, Charles Sikanic, down at Old Dominion University, worked out that we think is actually a good design for the lasers, so we're testing that out as well." Armando Hernandez '06, Sara Larocca '05, and Phil Ramon '06 are working on this as their St. Mary's Project.

This partnership has been extremely beneficial to students as they move onward to graduate work in their field—they have cutting-edge atomic physics work on their résumés at the undergraduate level. "This project has added another level to my college experience; being able to have hands-on experience working on relevant, state-of-the-art research has shown me possibilities of career choices after college," says Dan Link, who is working on his St. Mary's Project through this study.

Adler and Narducci have focused on creating an environment where students are not only welcomed and appreciated but where they also learn to understand the pressures of a real-life research task. "One of the things that Chuck and I specifically told them is that this is not only a project for your senior design that you'll kind of throw away. These are real projects with real deadlines… I've got to go to my sponsor and say, 'We got done what we said we'd get done,'" comments Narducci. "It's a real-world experience."

Students are also benefiting from working one-on-one with mentors like Adler and Narducci. Sara Goodale '05 comments that working with Adler on a one-on-one basis helps her to see that everyone goes through the process of trial and error in research. It "makes him seem more human," she comments.

Adler and Narducci agree that the St. Mary's Project pushes students to get involved with this type of research, and agree that the collaboration is beneficial for everyone involved. "Of the last 12 papers I've published, 10 have actually had undergraduate co-authors on them," Adler says, "We have a lot of contact time with students, so that's great." Students working on the project are not only profiting from the actual research they're doing, but from the experience of working so closely with faculty on real, viable research while they are still undergraduates.

Student Projects

TITLE: Design and Construction of a Virtual Pivot External Cavity Diode Laser for Atomic Physics Research
by Sara Larocca '05
Adviser: Charles Adler

This project focuses on the construction of a virtual pivot external cavity laser. One of the main objectives is to construct a laser that is mode-hop free. Mode hopping occurs when we are scanning over the wavelength of the laser. Instead of getting a continuous transition, the wavelength jumps discretely. This is detrimental to atomic experiments where the wavelength of the laser must be precise. When the laser beam comes out of the laser diode, it is split by a diffraction grating. Piezo-electric stacks (PZTs) mounted behind the diffraction grating rotate it, creating a 'virtual pivot.' If this is done correctly, mode-hopping should be eliminated from the laser.

TITLE: Atom Interferometry
by Daniel Link '05
Adviser: Charles Adler

This project is part of the Navy research that will aid in the production of an ultra-sensitive gyroscope, far more precise than the laser-ring gyroscopes in use today. Using the Magneto-Optic trap and the ultra-cold rubidium atoms that it can harness, St. Mary's students are able to work on important naval research through a partnership with Patuxent River Naval Air Station. To make use of the wave-like properties of atoms, a beam of atoms is directed through an atom interferometer, which interferes with them in much the same way that light can be interfered with. A key part of this project is creating a laser system that will be used as an atom beam-splitter by stimulating atomic Raman transitions. The project also incorporates work with optics, electronics design, and hollow-core optical fibers.