Statement of Teaching Philosophy

Chemistry

Aubrey McIntosh, Ph. D

Aubrey.McIntosh@Alumni.UTexas.Net

I like watching the light come on when my students first understand something. I have held classes of 10, 30, and 100 students and given fill-in lectures in classes of 500. I am comfortable with the interaction level in the 10 to 100 size range. I also think that my students like me.

In my own student years, I learned that teaching is a process whereby lifelong bonds between the faculty and alumni are forged. I have seen this in my own career as former students and employees tell other people that I am *the* person who gave them the spark of interest that grew into their new career interest, and I felt pride to hear this. This reaction is simply a gut response to the recognition that a student is a valuable human being entrusted to our care and I have discharged that responsibility well. My willingness to give students my attention and understanding nurtures their own sense of self-worth, and my demand for excellence and high standards gives them the prospect for success and prosperity.

Although it may be fine for me to have former students that are successful and praise my teaching and to have recommendations that say that I am smart and capable, I look for something more in this philosophical statement. The dual questions of *when does learning occur* and *how do we facilitate it* come to mind. The *when* question is akin to answering the riddle of when, exactly, does a man jump off a bridge. It cannot be when both his feet are in the air, because that moment is clearly after. And it cannot be when he still touches the bridge, because that moment is clearly before. However, we all know that there is a point between these two times that the man does, indeed, jump from the bridge.

In teaching there is also a point at which the learning occurs. It is before the student scores well on an exam and after he is confronted with a question that he does not know how to handle. There exists a point between these extremes where he is buttressed on one side with familiar territory, and confronted on the other with the open frontier. Learning occurs at this point, and teaching is largely the process of identifying this instant boundary of knowledge, making model problems that extend the boundary and document the newly gained knowledge, leading the student there, and holding high standards. This approach can give the science-phobic freshman humanities major confidence that science is accessible, and subject to the evaluation of educated laymen. This methodology passes the *grandmother test*, where an expert is judged by his ability to make his grandmother believe that *she* knows what he is doing. At the same time, this self-same approach is evident in the highest caliber work at the most elite of scientific conferences, research oriented Universities, or task forces solving current societal problems.

This viewpoint of when learning happens textures the ideas of how to facilitate learning. The professor must know his students and his subject material both, and choose his questions for that situation. Paradoxically indeed, the very questions and actions that are the best for a student today can be completely inappropriate for another student in the same class, or for the same subject next year, as the students' background and preparation change.

The most crucial skill is the ability to recognize the current level of comprehension in students, both individually and as a class. Although appropriate testing can aid this process, I have a quick mind and am adept at comprehending many differing viewpoints of the underlying subject matter. Following this assessment, I can create exercises that give a familiar conceptual framework for that particular student to work in, specific to the student's instant level of knowledge, and which lead the student to some important aspect of the subject where the student does not have mastery. My students say that I do this.

Course Preparedness Assessment

Chemistry

Aubrey McIntosh, Ph.D.

Aubrey.McIntosh@Alumni.UTexas.Net

In this section of courses, I can reasonably be expected to review textbooks, review prerequisites, consider curricular interactions, counsel students for preparedness, and produce lectures, exams, and homework on short notice.

Standard Courses

- General Chemistry
- Quantitative Analysis
- Instrumental Methods

Special Topics, Analytical

- Separations
- Mass Spectrometry
- Principles of Instrumental Design, including microprocessors

Lesser experience

- Inorganic Chemistry Lecture
- Organic Lecture and Lab

As I have 21 graduate hours in computer science, I also meet the minimum requirements of many regional accreditation agencies to teach computer science.

Undergraduate Research Program

Aubrey McIntosh, Ph.D.

Aubrey.McIntosh@Alumni.UTexas.Net

The Placement and Design of Undergraduate Research Projects

My daughter gardens, cooks, paints and photographs. I notice that she carefully reads books on folk knowledge, and avidly seeks out the grandmother wisdom on the use of indigenous and adapted plants. She keeps a notebook on her cooking trials. She reads critically, and reports to me that many current publications in herbal medicine are bunk. She sifts and sorts to find the truth. I see the scientist that I was 20 years ago reproduced in her.

At the same time, she worries that science is impersonal and irrelevant. She is surprised that much current activity in organic synthesis research springs from the finds of compounds in plants that have been identified by grandmother wisdom. She is innately a scientist, but rejects science based on a faulty public concept of science.

INTRODUCTION

Western civilization as we know it is inseparable from science. The appreciation of science, as well as the ability to critique and valuate scientific activity is an important skill for non-scientists. Yet we are living in a time where many people cannot even recognize science or distinguish it from an imposter. So at a very high level of importance, I desire to establish research projects where the character and philosophy of science are clearly evident.

In addition, both in the lab and in society at large, I perceive that it is important for people to be able to interact effectively. These interactions should work both close by, as well as across distance and through time.

Science is innately understood by children. They ask novel questions, propose answers, cross check their proposed answers against their knowledge, and go look for more knowledge if their base is not sufficient to confidently answer their question. This process **is** science. I am concern that in our quest to make more sophisticated tools in order to look at more inaccessible things, we have forgotten the rest of the process. We have confused the tool with the science, and we have forgotten the mystery and awe under the burden of dogma.

MY RESEARCH INTERESTS

My own research interests are 1) the development of new instrumentation, *i.e.*, an Arrhenius microdistillation probe for mass spectrometry, 2) the use of mathematical methods, chiefly factor analysis, to extract information from chemically relevant data, and 3) the use of chemometrics in chemical education infrastructure.

I believe that I can design a research project that has different components of persistence, remoteness, exotic conditions, exotic chemistry, and interaction with colleagues. I have taken the liberty to attach some current thoughts on projects that clearly address different mixtures of these attributes.

Undergraduate Research Program

Aubrey McIntosh, Ph.D.

Aubrey.McIntosh@Alumni.UTexas.Net

Development of new instrumentation
Arrhenius microdistillation probe for mass spectrometry

OVERVIEW

Gas chromatography - mass spectrometry is a widely used technique. The gas chromatograph separates the different compounds in a mixture into an almost pure state, and the mass spectrometer detects very small amounts of the compound, and identifies the molecular weight of the various fragments that the molecule can form. These systems are controlled by a computer, and this computer captures and manipulates the data that is produced.

An alternate design for an instrument replaces the gas chromatograph with a simple hot wire and a computer program. Both the electronics controller and the inlet probe, as well as the interpretation software are descendant projects from my dissertation and are amenable to an undergraduate project.

STUDENT EVOLUTION PATH

Students will learn the techniques of introducing samples into a high vacuum system. They will learn enough about electronics and operational amplifiers to produce a simple temperature control circuit. They will fabricate a simple probe that is similar to a standard hot-wire probe for mass spectrometry, but which can be programmed with a heating profile that is tuned for interpretation of the data by the Arrhenius equation. They will obtain data on pure compounds and simple mixtures, and reconcile the data with literature data for the compound.

PROFESSIONAL IMPLICATIONS FOR STUDENT

Control over instrumentation is as important in setting up experiments as the control over synthesis. However, as Richard Feynman noted, more and more scientists are using instruments that are commercial and *closed*, without the ability to freely open them up and change how they operate. The ability to create a circuit that is closely connected to some physical law, such as the Arrhenius equation, addresses the ever growing shortage of scientists who can operate, repair, or design instrumentation.

INSTITUTIONAL SUPPORT REQUIRED

A minimal mass spectrometer with a sample introduction port will be required. Students will produce artwork for printed circuit boards and have prototypes made. Some access to a chemistry machine shop will be required.

Undergraduate Research Program

Aubrey McIntosh, Ph.D.

Aubrey.McIntosh@Alumni.UTexas.Net

Development of new instrumentation
Remote Sensing of Air Pollution

OVERVIEW

Ozone depletion, propagation of industrial emission plumes, and propagation of smoke from forest fires are well known public interest items which are accessible to undergraduates using available technology. The most astonishing example is the Forrest Mims device disclosed in Scientific American in 1977, along with seven years of collected data on atmospheric haze, using a device that costs less than $20 to build.

A national network of such devices can be built and placed in the internet at cooperating institutions.

STUDENT EVOLUTION PATH

Students will be introduced to absorption and fluorescence spectroscopy and some electronics then do literature preparation on LIDAR (laser detection and ranging). They will also do library research on newspaper accounts of remote sensing of pollutants under antagonistic conditions. The utilization of the sun as a calibrated, universally accessible component in a large-scale full atmosphere spectrometer will be introduced. Recent results in calculating the limits of detection, standard deviation, and other figures of merit in simultaneous mulitcomponent analysis calibrations will be introduced. A body of data will be collected, and the methodology and implications of multi-year, multi-personnel projects will be emphasized.

Students will eventually desire to profile analyte concentrations according to altitude or exact location. This requires multiple light paths and deconvolving software. Future development in low level light detectors and increased computation power will allow the use of stars as light sources. The deployment of an array of devices using different stars can be coupled with computer tomography data analysis techniques to produce a spatially resolved analysis of atmospheric chemistry.

PROFESSIONAL IMPLICATIONS FOR STUDENT

Designers of instrumentation and experiments often fall into the paradigm of scaling up a bench prototype at considerable expense. The alternative of using *found* materials in a scientifically rigorous way can allow collection of field data under chaotic conditions. The awareness of *found* materials in turn encourages the perception of analytical chemistry as a discipline with relevance.

INTERDISCIPLINARY IMPLICATIONS

As US population develops, as Western technology diffuses to new population centers, and as large populations rise in annual income and thence incorporate comsumer patterns, the potential impact of Man on the environment increases dramatically. In addition to ethics, a compassionate viewpoint, and an awareness of societal pressures, policy advisors need reasonable measurements of the impact of urbanization: this project can provide such data. Graduates of this project can produce and evaluate such measurements.

INSTITUTIONAL SUPPORT REQUIRED

Roof access in a protected location; an existing weather station location would probably suffice. A budget for optics, optoelectronics, and encasing boxes. Tthe project can produce a small number of instruments of which the department retains ownership and posession, or the project can be set up so that each student keeps their instrument at graduation.shop fee to produce the basic experimental device would be needed.

Undergraduate Research Program

Aubrey McIntosh, Ph.D.

Aubrey.McIntosh@Alumni.UTexas.Net

Use of mathematical methods to extract information

Synthesis of 7-substituted Coumarins in support of Factor Analysis applied to C-13 NMR Chemical Shifts

OVERVIEW

Analysis of NMR shifts reveals factors that have a similarity to the venerable Hammet substituent values. These shift series differ slightly when the base molecule is different, and like the Hammett series, the entire set of data from a wide set of series can be combined into a small number of independent factors. Students synthesize different 7-substituted coumarins and obtain the proton and C-13 NMR spectra.

STUDENT EVOLUTION PATH

Students entering the project are expected to know the mechanics of producing a literature reference paper and to have the first semester organic laboratory skills. As a group, they do a three to four week literature research on the synthesis of coumarins, and propose a methodology to produce the substituted coumarins. For example, they may use variously substituted salicylaldehydes or phenols and do a ring closure, or they may attempt electrophillic attack on the courmarin molecule.

The group proposes two pathways to synthesize the target molecules, and make a list of starting materials to be procured. On approval, the materials are procured and the synthesis is attempted.

NMR spectra of the molecules are obtained, and the shift assignments are made. These results are delivered to me for my back project on factor analysis

PROFESSIONAL IMPLICATIONS FOR STUDENT

This project is frequently the first time that the **students directly exert their will over matter and cause change**. The coumarins are a rich family of compounds that have natural product, medicinal, and laser dye applications. Many are brilliantly fluorescent, and so they can be detected visually and cause student excitement even when the yields are low.

OPPORTUNITY FOR COLLABORATION

Researchers in optronics typically do not have strengths in synthetic organic chemistry, and chemistry students typically do not have strengths in high power nanosecond electronic circuits or high power optics. Collaborations are being explored with optronic researchers who are interested in characterizing new laser dyes.

INSTITUTIONAL SUPPORT REQUIRED

The students need access to a library, a synthetic organic chemistry lab, a small budget for precursors and NMR solvents, typically $120 / 3 students. The presence of a double scanning fluorimeter adds an additional dimension to the project.

Faculty Research Program

Aubrey McIntosh, Ph.D.

Aubrey.McIntosh@Alumni.UTexas.Net

Chemometrics in chemical education infrastructure

Supervised Peer Grading in the Large Classroom

OVERVIEW

One career progression is for bench chemist to eventually turn their intellect to the chemical education process, *per se*. I am in that transition, and I advocate the use of supervised peer grading to improve the overall learning that students achieve in a classroom.

Human grading has some attractive characteristics over some other assessment methods currently being used. In particular, the *Scantron* is a popular method of recording student answers to questions. The type of questions which are amenable to Scantron grading de-emphasize recall, discretion, and creativity, the very attributes that we desire prospective societal leaders to develop in college. Human graders have a significantly better ability to grade these types of questions.

Students who grade become more acutely aware of the issues that the grader considers. This awareness allows the students to submit work that is of higher quality. The implication is that *student grading* is a desired activity to produce quality graduates.

When a panel of peers does the grading, the instructor is confronted with a vast quantity of raw numbers, which must be interpreted in a coherent manner to produce grades. These numbers reflect various biases (assumed rubrics) that the students may have. For example, the *neatness vs content* valuation is different for almost every grader.

I have turned to analytical chemistry for insight to handle these numbers. Modern instrumental systems produce vast quantities of raw numbers. For example, a gas chromatography / mass spectrometry experiment that measures the *m/z* ratios of 15 - 300 Daltons at 10 spectra / second for 15 minutes produce 2,565,000 individual ion intensity measurements. The signals of chemical interest are typically the mass spectrum of a pure compound, and the chromatograph (time evolution of the intensity profile) of that pure compound. In a typical real experiment, there are more pure compounds evident in the data than the chemist expects. For example, a compound from Aldrich tested for purity and identity will give gc/ms data that has 1) solvent, 2) air leak, 3) silicone compounds from the injection septum, 4) major component, and 5) impurity. This data is typically very noisy.

Factor analysis is one technique used by the chemometric community to process this type of data so that a comprehensible view of the raw data can emerge for the chemist. These techniques work in the presence of unexpected additional components, and are used to determine the number and the nature of unexpected components. The chemometric literature also has techniques to manage the missing data problem.

When factor analysis methods are applied to peer grading data, issues such as collusion and retaliation, neatness vs content, or other disagreements in the grading are identified. The grade without these pathologies are recovered, and the specific graders and papers that represent the pathologies are identified. Recommended scores for a re-grade request are available to guide students to producing quality grades, and the *quality of grading* itself is available for the instructor to include in the course grade.

WORK TO DATE

A factor analysis engine is available from my dissertation work. Preliminary work has been done with small groups of students. Work is underway to connect the grading engine to the web, and to automate the submission and assignment of laboratory notebooks, which will be used in the preliminary grading assignments. A manuscript is in preparation which describes the mathematical theory used to identify pathological grades, and to give a grading hint for the misgraded item.

Worksheet toward syllabus for Advanced Instrument Design

Embedded Systems Concepts

Syllabus

Summer 2003 Offering

Students in the **embedded systems concepts** course reproduce a digital electronic product. The course provides guided hands-on experience walking through an existing design of hardware and software sub-systems and submitting them to prototype production. Students work in teams of three. The students keep the finished product.

The project for the Summer 2003 course is a computerized RS-232D cable, built around a PIC 16F877 processor, using CadSoft EAGLE schematic capture software. At the end of the course, students will be positioned to *produce* a small or hobby design, independent of the instructor, utilizing subcontractors at any stage where appropriate.

The class has been structured into design teams. Each team has a balanced experience base controlled by admission selectivity. One student may be learning software; another, hardware; and another, project management. However, each student brings experience as well, which may include software experience, hardware experience, or additional experience to balance the team. The pace will be accelerated, and to succeed the student teams must work closely together.

The instructor holds the fundamental philosophical position that graduates must learn how to perform, how to work with others, and how to transfer selected knowledge to the future. Additionally, this is taught as a design course from a liberal arts point of view; that is, you develop and express your view of how the future should be.

Weekly Schedule

1. **Introductory Remarks**. Often, embedded systems are small computer projects that interface to *appliances*, instead of keyboards and terminals and they react *right now* instead of sometime later. When the interface is visible, it has pushbuttons, lights, and beeps and not filesystems and pages of text. Sometimes, the interface is completely hidden from the user. A digital watch, the air conditioner thermostat, the panel control on a pH meter, the fuel and spark control for an auto engine are embedded systems. An embedded system always has some pesky detail as the core requirement that is the *only* care that the customer has, and which was not ever covered in your computer background. A single mother with a hungry child and water all over the apartment floor doesn't view your difficulty with water level sensors with empathy.

Teams will present a 1 to 3-page description of the Mark I Star Trek serial cable. *Hints*: Is the protective cover photovoltaic? Does it auto-translate? Does it die *when* you put it in the wrong plug? Can it assume a different personality? Can your computer talk to it, itself? Can two cables help each other? Does it report pH if you dip it in Coca-cola? Can it call home if Fred takes it again? This must be clear enough for a stranger at a bus stop to understand, more interesting than the other project the investor read, ethical enough that you won't blush if your grandmother finds it, easy enough to do. Hard assignment? Yes, but worthy.

2. **Introduction to software programming.** The students will read the data sheets for the processor, write the general concept for a program to activate LEDs connected to the PIC, submit the code to requirements review and revision, score each teams design, write the actual software under their revised design, flash the program into the PIC on a provided circuit, and demonstrate the working code. Students will then have a flashing-light cocktail-table discussion piece. Students keep a current notebook.

3. **Introduction to serial communications.** Students will read the data sheets for serial communications on the PIC 16F877 microprocessor, read additional information on RS-232D serial communication available on the web, send serial data to the PIC, and use the LEDs to diagnose and confirm operation of the system. User-friendly diagnostic messages, such as the *baud rate*, *parity*, and the presence of *DTR, DSR* and other handshake signals will be sent to the alternate RS-232D port. Interrupts, the UART subsystem, and the PWM subsystem will be used. Students will then have a minimal capability RS-232D communication verification device. Students keep a current notebook.

4. **Introduction to In Circuit Low Voltage Serial Programming.** The students will read the data sheets for in circuit serial programming for the PIC midrange devices. They will connect jumpers from the sockets used for the LEDs to the IC-LVSP port on a companion board. They will use provided windows based software to send code through the serial port on a workstation to the companion board, and cause the target board to be programmed. Any two students will possess all necessary boards, software, and experience to program additional PIC devices. Students keep a current notebook.

5. **Introduction to packetized communication.** Students will build a safe self-programmer based on an instructor provided private packet format. Students will be able to modify programs in their own boards without additional boards or materials. Students keep a current notebook.

6. **The Outside World, Onsite Monitoring, and Data Logging.** Students will read the data sheets on the A/D subsystem. They will write a program to make measurements of the voltage on a fixed pin of a RS-232D connector and report it back. Problems in connecting to the outside world will be considered in the scope of the line driver and receiver and in view of their data. Data will be time stamped and stored at a central host. Students will now have a cheap, slow datalogger. Students keep a current notebook.

7. **Diagnostics.** Students will write code to read the values on the handshake lines on the RS-232D connector, and to correctly drive the other handshake lines in response. Students will design software to work despite common deliberate deviations from RS-232D, and to log the deviations, compensations, and outcomes. Students keep a current notebook.

8. **Introduction to CadSoft EAGLE schematic capture and board routing software.** Circuit board layout is an art form that requires significant practice and is beyond the scope of this course. However, minimum competence with the schematic and board files is necessary to present improvements to the future. Schematic capture, Board placement, library component editing, autorouting, and design rule issues will be presented. Students will have a freeware version of the software, capable of producing all the boards used in the course. Students keep a current notebook.

9. **Critique of boards provided in the course.** Each group will make a presentation to the class of a shortcoming of the current board design, and the impact the shortcoming had on the software production. Troubleshooting support and optimistic requirements are important areas of concern. The Mark II Star Trek serial cable is described. Priority will be given to changes that have strong support by a notebook entry.

10. **Modification and submission for manufacture of next generation boards.** Students alter the schematic and board files to meet the new requirements documents. They will submit their files to a board house. They will have a choice to keep either the new boards or the original boards.

11. **Production of final project report.** Students will write a report on the course and make a presentation of their findings. Changes to both the student's and the instructor's packet will be made, including bill of instructor's materials, pace and timing hints, compatibility with existing products, choice of hardware, software, and project, and student's packet specification. The report should be ready for a limited production run in the genre of the Star Trek technical manual series. Students will possess enough material to allow an experienced instructor to produce the course. Goodbye and good luck!