Developing the third year integrated Chemistry Laboratories: Overcoming challenges and putting the pieces back together

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Traditional Course Structure

- *Laboratory components of related lecture courses*

CHEM 313/330: *Advanced Organic Chemistry*

CHEM 311: *Instrumental Analytical Chemistry*

CHEM 304/305: *Fundamentals of Physical Chemistry/Biophysical Chemistry*

CHEM 309/310: *s- and p- block/ d- and f- block Elements*

Integrated Course Structure

- *Laboratory course is stand-alone course*
- *Experiments across all sub-disciplines*

CHEM 3XX (315/325/335/345):
- Chemistry, Biochemistry, Combined Major in Science (CMS), BLMSc Programs
- 300+ Students

Goals Post-Structure Change

- Re-align and/or introduce new assessments that better meet course goals
- Provide learning goals for each experiment
- Harmonize student experience over disciplines
- Transition from autonomous to collaborative faculty experience
- Continued evaluation of course content and changes made (via research projects, student surveying, course mapping)
- Streamline scheduling for students (develop software)
- Move toward more integrated approach (develop new experiments)
- Introduce TA training initiatives that specifically target challenges of the course

As the new instructional model was adopted, some benefits of the traditional model were lost and new challenges emerged (logistical, teaching, and learning):

Sub-discipline Specific Challenges and Mitigation Approaches

The Organic Chemistry Laboratory:

Traditionally run on a single experiment basis; consistent experience (lab director delivers prelab talk, students work individually on same procedure, systematic skill building, repeated practice; supervised by the same TA over the term, graded on report, technique and product by same TA).

- Students with various organic experiences – CHEM/BIOCHEM (2 terms) CMS (one, different lab space) Transfer (varied)
- ✓ Students can arrange personal tour and description of organic lab routines. In-lab training by lab director on "as needed" basis
- Students need to complete additional steps after dedicated lab period
- ✓ use CLaSS (scheduling software) as a communication and feedback tool, e.g. data entry column dedicated toward letting students know samples are ready for further analysis
- TAs need to be experts in multiple experiments - limited hours to accomplish this since their allocated time is consumed by contact hours in lab and grading
- ✓ Trello as resource and TA-TA communication on points of technique, prelab and report grading schemes, areas to provide comments/feedback

The Inorganic Chemistry Laboratory:

Previous run as a component of the lecture course. Limited availability of equipment results in (i) students rotating through various workstations throughout term (in no particular order), and (ii) mostly conducting experiments in pairs.

- TA workload and ratio of students/TA off-balance as students create schedules. Sometimes this ends up with one TA/student
- ✓ Review of scheduling to maximize resources for a given lab day
- Experiment conducted in pairs; student pairs with differing backgrounds can result in differences in the extent of data analysis and characterization tools used. TA has to manage and provide information accordingly.
- ✓ More generalized background information files provided so that everyone has a similar baseline

The Analytical Chemistry Laboratory:

Analytical chemistry labs have a single lab period (one experiment) as the pedagogical building block. Students cycle though experiments in no particular order. Students normally work in partners. Consistent pre-lab, in-lab and post-lab assessment methods. Students are graded on lab report, technique and accuracy of results.

- Students rotate between partners; hard to build trust in each others abilities and portion of grade is joint to the partners.
- Introduction of CMS and biochemistry students to analytical labs broadens and weakens backgrounds of students. This is particularly challenging for analytical-specific skills (pipetting, uncertainty analysis).
- ✓ Instructor led 'boot-camps' on particular topics. Extra attention paid to instructor knowing who is new to the lab. Development of on-line primers on particular topics.
- Student choice can leave student with no experiments within important areas of analytical chem.
- ✓ Introduction of instructor selected, mandatory experiment(s)

The Physical Chemistry Laboratory:

Previous run as a component of the lecture course. Limited availability of equipment results in (i) students rotating through various workstations throughout term (in no particular order), and (ii) mostly conducting experiments in pairs. Students graded on lab report, technique, and quality of results.

- Student load in physical chemistry labs is high – increased CMS and chemistry students (previously CHEM 305 was mostly biochemists)
- ✓ Run all experiments at the same time, develop new experiments
- ✓ Give more choice to biochemists by opening up offerings in other analytical and inorganic
- Making lab experience interesting for a range of students (biochemists, CMS, chemists)
- ✓ Developed new physical chemistry experiments for CMS and chemistry majors
- ✓ Developed new integrated experiments for chemistry majors
- ✓ Future plan: develop integrated experiment for CMS
- Physical chemistry concepts are challenging for students without having learned lecture content
- ✓ Improved background information in laboratory manual
- ✓ Developed questions to guide students in preparing lab report discussion.

Cross-Course Challenges and Mitigation Approaches

Student not consistently in one lab space or interacting with one instructor or TA - often fail to pick up lab reports, get feedback necessary to improve
- ✓ Report wrappers introduced 2015/2016 for set of experiments

Sharing of lab reports, excel spreadsheets, etc.
- ✓ Oral reports, final exam as alternative assessments
- ✓ Changing lists of questions being asked each year may help

Lack of understanding of inner-workings of instrumentation
- ✓ Instructional videos as additional training and resource

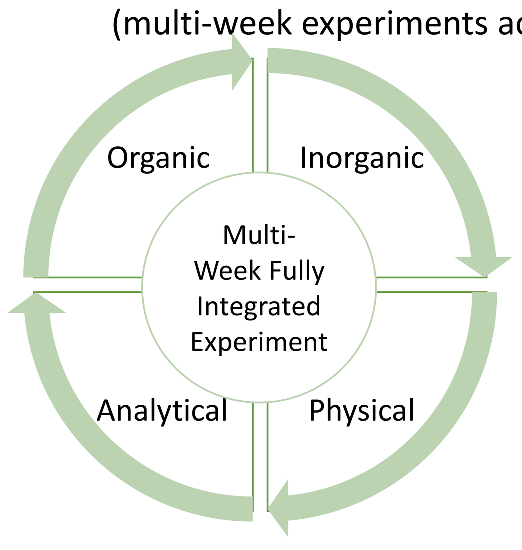
Managing rotation between and expectations of different sub-disciplines, instructors, TAs
- ✓ Developed common grading rubric for technique mark, common safety quiz
- ✓ Mandatory orientation session in each physical space students will be working

Various student backgrounds in single course (due to major, course sequence within program, knowledge/skills level)
- ✓ Pre-laboratory exercises and readings emphasize important background information
- ✓ 2-hr workshop for all TAs working in course related to teaching strategies, assessments
- ✓ Experiment offerings tailored to background (based on course sections)

No 'required' textbooks

Future Plans

- Continue review of assessment strategies in course as a whole and to develop new approaches consistently across all sub-disciplines
- Improve pre-laboratory exercises to meet all student needs
- Work out remaining logistical issues
- Move toward true integrated experiences (multi-week experiments across all labs)



- ✓ higher level of inquiry
- ✓ realistic chemistry experience
- ✓ work across all lab spaces for one experiment

Highlights and Outlook

Course Mapping:

- cognitive tasks in experimental research[1]
- skills/knowledge taught or practiced in pre-requisites and/or 50+ experiments
- examine cognitive demands on students
- inform development of new experiments & decisions on choice restrictions
- map progression from 1st-4th year

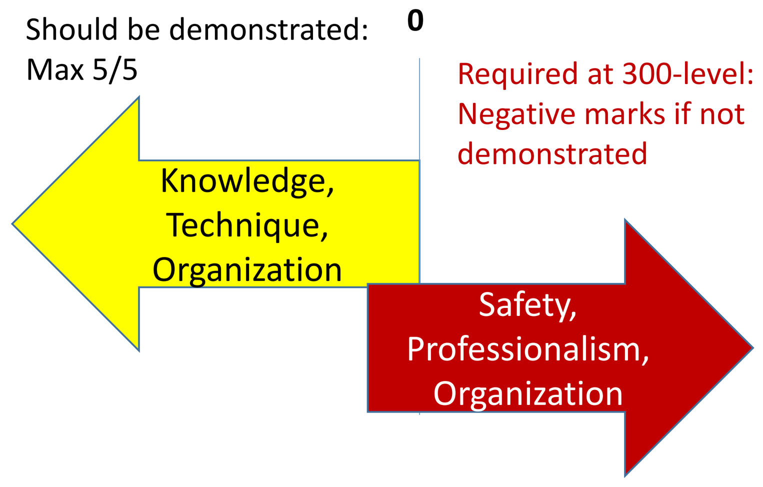
3XX Physical Experiments: Example skills/techniques taught (T) in course, practiced (P), or part of pre-requisite courses (PR)

General and "Soft" skills	Learn basic Lab notebook standards	PR
	Develop expt procedure (experimental design)	
	Troubleshoot lab procedures	P
	Basic glassware use (buret, pipet, flasks, beakers)	PR
	Learn pH probe calibration and use	T
Physical	Basic gas handling techniques	T
	Measurement of pressure (barometer use)	T
	Direct' measurement of Delta H, Delta S	P
	Reaction kinetics, determine Ea and reaction order	
	Ro-vibrationnal spectroscopy (fundamentals)	T
	Thermodynamics of non ideal systems	T
	Surface chemistry	T

Changes to Assessments

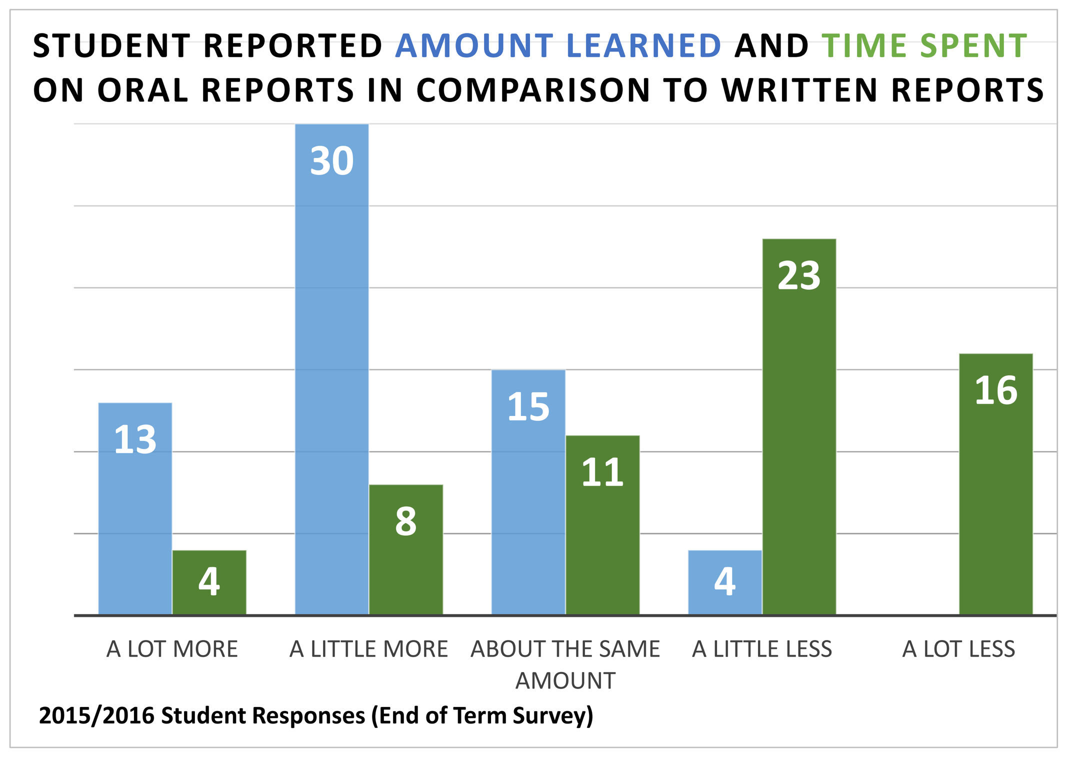
- Oral reports and discussion
- Written final exam
- Common in-lab rubric
- Post-report reflection (wrappers)

In-lab technique rubric model: 5/5 to -3



TA Training

- 2-hr workshop & Peer-mentorship



<u>Report Wrappers</u>
- 80 % completion rate
-average number of resources reported to have been used by student per report: 4.4 (Oral), 3.8 (Written)

<u>Example prompt:</u> *"Name one or two approaches you may use to improve upon your chemistry reports in the future"*
<u>Example Answer:</u> *"To more closely analyze the reagents and products, including all relevant spectra. To try to understand how the intended product forms, mechanistically, while comparing with the procedure"*

Ongoing Projects and Areas for Improvement

- Develop additional integrated experiments, increased level of inquiry
- More effective pre-laboratory exercises
- Continued review of assessments and alignment with course goals
- Workload concerns
- Research study on learning from oral reports vs. written reports

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1. C. E. Wieman, "Cognitive tasks involved in carrying out experimental research"