Implementation of an “Introduction to Experimental Chemistry” Course

within
Before and After Lab: Instructing Students in “Non-chemical” Research

Kim Woznack
Gregg Gould, Matthew Price, Ali Sezer, Min Li
California University of Pennsylvania
woznack@calu.edu
Outline

• Where is Cal U?
• Motivation for New Curriculum
• How Cal U addresses Non-chemical Research Skills
  • CHE 104: Introduction to Experimental Chemistry
  • Lab Notebooks Activity in Intermediate Lab I
  • Lab Reports Activity in Advanced Lab I
  • Seminar Presentation in Research I
  • Poster Presentation and Written Report in Research II
Cal U Campus
Cal U- Regional Public University

- Founded in 1852
- ~7500 undergraduate students (~9000 total)
- ~290 full-time faculty
- Southwestern PA- 35 miles south of Pittsburgh
- California State Teachers College (1952)
- $3120/semester (2011-2012 in-state tuition)
- 150 majors: Associates, Bachelors, and Masters Degrees
- PSAC, NCAA Division II
- The Cal U Vulcans!
Our Former Laboratory Program

Former labs linked directly to courses

✖ Did not nurture research capabilities in students.
✖ Did not emphasize overlap of the disciplines of chemistry, particularly with regard to laboratory work.
✖ Heavy teaching burden at 3 hours per lab.
✖ Inhibit ability to offer Foundation courses on annual basis.

★ Our goal is to achieve ACS approval of our program.
★ Removed lab portion from most CHE courses (Organic II, Inorganic, Physical I & II).
★ Merged Analytical and Instrumental Methods into one course without a lab.
Non-chemical Research Skills

- Career Options for Chemists
- Search & Read the Chemical Literature
- Manage Literature References
- Ethical Issues associated with Research
- Safety Information & Practices
- Understanding the Peer Review Process
- Presenting Research- Presentations & Posters
- Publishing Research
- Acquisition of Research Funding
CHE 104: Introduction to Experimental Chemistry

- Two credit non-laboratory course to kick-start the integrated lab program.
- For chemistry majors: incoming first year and transfer students ONLY.
- Develop a learning community or cohort since they are with the general student population in General Chemistry I & II.
- Demonstrate our expectations for the entire integrated lab program.
- Provide a set of reference materials students should refer back to during the duration of the lab program.
- Enrollment is typically 10-15 students.
- Our first group will be seniors this year. (First taught in 2009)
Evaluation of Students in CHE 104: Introduction to Experimental Chemistry

- Exams (3 @ 15% each) = 45%
- Quizzes = 15%
- Assignments = 20%
  - (both in class and take home)
- Final exam = 20%
Experimental Chemistry, Topics Covered

1. Future as a Chemist/ Careers
2. Scientific Method/ Ethics
3. Experimentation/Measurement
4. Experimental Design: Density Lab Activity
5. General Lab/Chemical Safety
6. Compressed Gases/ Vacuum systems
7. Uncertainty/Significant Figures
8. Utilizing Excel
9. Data Analysis Autopipets Lab Activity: Statistics
10. Data Analysis: Error Propagation, more Stats
11. Chemistry Literature: Using Library Resources
12. Interpolation/Extrapolation
13. Molecular Modeling Software
CHE 104: Chemical Literature Project

- Perform a literature search and describe how you carried out the search. Define the title.
- Why is the work important?
- In what realm of chemistry (analytical, biochemistry, environmental, inorganic, organic, or physical) is the work?
- What is the work related to?
- What problem is the author trying to solve?
- What are the measured variables? the controlled variables?
- Was the accuracy of the results measured?
- What are the most important findings of the study?
- Are the results presented in an organized way? Briefly Explain.
- How do the tables, figures, diagrams help reveal or explain the findings of the study?
- Did the authors solve the problem? What did the authors conclude? What if any additional experiments are suggested or planned by the authors?
- How many references are reported in the paper? Break down the types of references into journal articles, books, etc.
Our New Integrated Lab Program

Six new lab courses introduced:

- Intermediate Chem Lab I & II
- Advanced Chem Lab I & II
- Chemistry Research I & II

Note that all courses are “majors only” and all are team taught by all 5 chemistry faculty members.
Other Non-chemical Research Skills in the Integrated Lab Program

- Increasing Lab Report Expectations

Laboratory Report Writing Expectations for the Integrated Chemistry Lab Program:

<table>
<thead>
<tr>
<th>Lab Report Sections</th>
<th>Intermediate Lab I</th>
<th>Intermediate Lab II</th>
<th>Advanced Lab I</th>
<th>Advanced Lab II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>Abstract</td>
<td>Abstract</td>
<td>Abstract</td>
<td>Abstract</td>
</tr>
<tr>
<td>Introduction</td>
<td></td>
<td>Introduction</td>
<td>Introduction</td>
<td>Introduction</td>
</tr>
<tr>
<td>Experimental</td>
<td></td>
<td>Experimental</td>
<td>Experimental</td>
<td>Experimental</td>
</tr>
<tr>
<td>Results</td>
<td>Traditional Handout with Directed Questions</td>
<td>Guided Data Collection</td>
<td>Results</td>
<td>Results</td>
</tr>
<tr>
<td>Discussion</td>
<td>Traditional Handout with Directed Questions</td>
<td>Guided Discussion</td>
<td>Discussion</td>
<td>Discussion</td>
</tr>
<tr>
<td>Conclusions</td>
<td>Traditional Handout with Directed Questions</td>
<td>Guided Conclusions</td>
<td>Conclusions</td>
<td>Conclusions</td>
</tr>
<tr>
<td>References</td>
<td></td>
<td>Guided Referencing</td>
<td>References</td>
<td>References</td>
</tr>
<tr>
<td>Appendices</td>
<td>Appendices</td>
<td>Appendices</td>
<td>Appendices</td>
<td>Appendices</td>
</tr>
<tr>
<td>Sample Calculations</td>
<td>Guided Data Treatment</td>
<td>Sample Calculations</td>
<td>Sample Calculations</td>
<td>Sample Calculations</td>
</tr>
</tbody>
</table>
## Student Evaluation in Intermediate and Advanced Lab Courses

<table>
<thead>
<tr>
<th>Course Component</th>
<th>CHE 371/372 Weight</th>
<th>CHE 471 Weight</th>
<th>CHE 472 Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-laboratory Notebook Work</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Pre-laboratory Quiz</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Laboratory Notebook Entries</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Laboratory Safety Standards</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Lab Report Exercise</td>
<td>------</td>
<td>5%</td>
<td>------</td>
</tr>
<tr>
<td>Final Laboratory Report Write-up</td>
<td>50%</td>
<td>55%</td>
<td>60%</td>
</tr>
</tbody>
</table>
CHE 371: Intermediate Lab I

- Introductory Activity: Determining Density of Rubber Stoppers

The dimensions of the rubber stopper, $d_1$, $d_2$, and $h$, will be used to calculate the volume according to equation 1.

$$V = \frac{\pi}{12} h (d_1^2 + d_2^2 + d_1 d_2)$$  

- Students can comfortably do the measurements themselves and write their lab notebook entries. Alternatively, “sample student page” can be provided for review.

- Student can then self-evaluate, peer evaluate, or evaluate samples using the lab notebook grading rubric.
# Lab Notebook Scoring Rubric

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight (Total of 20 pts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Appearance</td>
<td>0-1 pt</td>
</tr>
<tr>
<td>Scientific Language Throughout</td>
<td>0-1 pt</td>
</tr>
<tr>
<td>Attached Computer Generated Graphs/Tables</td>
<td>0-2 pts</td>
</tr>
<tr>
<td>Proper Units Throughout</td>
<td>0-2 pts</td>
</tr>
<tr>
<td>Data Collection (completeness, sig figs)</td>
<td>0-2 pts</td>
</tr>
<tr>
<td>Results (completion, sample calculations)</td>
<td>0-4 pts</td>
</tr>
<tr>
<td>Discussion (appropriate and complete)</td>
<td>0-6 pts</td>
</tr>
</tbody>
</table>
CHE 471: Advanced Lab I

- Introductory Activity: Determining Density of Rubber Stoppers
- Emphasis on Lab Report Writing Skills (5% of overall course grade)
- Students can comfortably do the measurements themselves and write lab notebooks and lab reports. Alternatively, “sample lab reports” can be provided for review.
- Student can then self-evaluate, or evaluate anonymous peer lab reports using the lab report grading rubric.
- Spring 2012 the students did experiment, wrote notebook entries, wrote lab reports and peer-reviewed an anonymous peer paper.
Sample of CHE 471 Student Feedback on Introductory Density Activity

Name: Jane Smith

Score for Introductory Exercise, Density Lab Report:

Dr. Woznack’s score for your Density Lab Notebook Grade: 17 / 20 points

Dr. Woznack’s score for your own Density Lab Report Grade: 60.5 / 78 points

Points assigned for Quality of Peer-review you performed: 10 / 10 points (see details below)

Your total Grade for Introductory Exercise: 87.5 / 108 points (5% of your overall grade)

Peer Review Performed by you of another paper:

Score you assigned: 64 / 78 pts  Score Woznack Assigned of same paper: 66 / 78 pts  Difference: 3

0-5 pt difference = 10/10 peer review score,
5-10 pt difference = 8.5/10 peer review score,
10-15 pt difference = 7/10 peer review score
<table>
<thead>
<tr>
<th>Cover Page/ Abstract/ Introduction (16 points)</th>
<th>1 page Cover page 2 page Introduction</th>
<th>A title page is present at the beginning of the report with title, name, date, course, and abstract.</th>
<th>A focused abstract with a statement of what was done and the important results is included (w/correct sig figs and uncertainty).</th>
<th>The introduction has a clear objectives statement in the first paragraph that accurately reflects the purpose of the lab.</th>
<th>The introduction is clear, focused, and ordered. The reader is able to follow and analyze all results. Significant points deducted if not properly completed.</th>
<th>In the introduction, all equations, tables, figures, and referencing are numbered and follow the required formats.</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental (5 points)</td>
<td>1 page Total</td>
<td>Important equipment, chemicals, etc. are included. This includes the names of manufacturers and other relevant information.</td>
<td>A brief but clear description of the experiment is given (with a schematic if necessary). This information should define the task without unnecessary detail as followed in examples provided.</td>
<td>Correct grammatical and technical writing formats are used (past tense).</td>
<td>Comments:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw/Collected Data (includes tables, spectra, chromatograms, etc.) (8 points)</td>
<td>Raw/collected data are complete.</td>
<td>Raw/collected data are reported with proper units, sig figs, and uncertainty.</td>
<td>All raw data are presented in an organized way, with proper figure number, captions, labels.</td>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Analysis  (18 points)</td>
<td>All required data processing or analysis is complete.</td>
<td>All processed data are reported with proper sig figs, units and uncertainty.</td>
<td>All processed data are presented in an organized way, with proper figure number, captions, labels.</td>
<td>Quality of experimental results as measured by precision, accuracy, percent yield, etc.</td>
<td>One sample of each calculation is provided in an appendix. Handwritten work is acceptable.</td>
<td>Comments:</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Results/Discussion 2 pages Total (18 points)</td>
<td>A logical presentation of results is provided with proper linkage to previous relevant tables, equations and figures. Must include references to all raw and processed data.</td>
<td>In the narrative of this section the results are reported with proper units, sig figs and uncertainty.</td>
<td>The discussion includes integration of experimental results with fundamental chemical principles.</td>
<td>An evidence-based discussion of the quality of experimental results as measured by precision, accuracy, percent yield, etc. is included.</td>
<td>Specific, logical, and complete suggestions for error and improvement of experiment are provided.</td>
<td>Comments:</td>
<td></td>
</tr>
<tr>
<td>Conclusion / References (7 points)</td>
<td>A short but to-the-point conclusion is provided with quantitative and specific statements about what was accomplished with the experiment.</td>
<td>A list of references (of which three must be primary) is provided after the conclusion in the appropriate ACS format.</td>
<td>References are cited properly throughout the report.</td>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Evaluation (6 points)</td>
<td>All page limits and margin requirements are followed in the preparation of the lab report.</td>
<td>Correct grammar and spelling are used in the text as well as technical writing language as demonstrated in the instructional packet.</td>
<td>References are cited properly throughout the report.</td>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL 78**
<table>
<thead>
<tr>
<th></th>
<th>CHE 491 Weight</th>
<th>CHE 492 Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Notebook</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Lab Accomplishments</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>Safety Standards</td>
<td>10%</td>
<td>--------</td>
</tr>
<tr>
<td>Seminar Presentation</td>
<td>50%</td>
<td>--------</td>
</tr>
<tr>
<td>Poster Presentation</td>
<td>--------</td>
<td>25%</td>
</tr>
<tr>
<td>Final Written Report</td>
<td>--------</td>
<td>40%</td>
</tr>
</tbody>
</table>
Non-chemical Research Skills

- Career Options for Chemists
- Search & Read the Chemical Literature
- Manage Literature References
- Ethical Issues associated with Research
- Safety Information & Practices
- Understanding the Peer Review Process
- Presenting Research- Presentations & Posters
- Publishing Research
- Acquisition of Research Funding
Acknowledgements

- Co-Authors & Our Families
- Taxpayers of Pennsylvania
  - public institution
- Faculty at Cal U
  - (performance funds)
- Students at Cal U
  - (technology fees)
- Chemistry Majors
  - (patience & course substitutions)