Real Research / Real Genres: Integrating Research-Based Writing into an Introductory Chemistry Sequence for Majors

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CH111/CH112 Course Structure

Standard, honors-level first-year chemistry course sequence

- Lecture (3 hrs), discussion (1 hr), pre-lab lecture (1 hr), and lab (4 hrs)
- Students take first-year writing concurrent with CH111

Types of assignments in lab portion of the course

- Post-lab questions (5 in fall, 2 in spring)
- Formal lab reports (5 in fall, 4 in spring)
- Capstone project (team-based research project in spring semester)

Division of instructional labor

- Course Instructor: Full-time lecturer / instructor
Hiring, training, and content creation
- Writing Assistants: Graduate students in science fields (CH and others)
Confer with students; comment on, grade writing
- Teaching Assistants: Graduate students in Chemistry
Grade papers on technical merits

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Year 0 (2008-09) Assignment Sequence: Baseline, Standard Lab Assignments

- Formal lab reports for every other lab (~5 per semester)
- Students receive a five-page “Basic Guide to Writing Lab Reports”
- No explicit, in-class writing instruction
- ~**20** hours, ~**50** pages per student/semester

Year 1 (2009-10) Assignment Sequence: Follows Conceptual Logic of Scientific Content

- Meetings with writing assistants were optional
- Instruction was all done in-class (pre-lab lecture), i.e. no handouts
- No new writing assignments, no fewer writing assignments – all work was done on the existing lab reports
- Final approval for the three-year pilot in Spring 2010
- No substantive change in writing "effort" (~**20** hours, ~**50** pages)

Cumulative Lessons Learned

- Year 1 – Follows Conceptual Logic of the Scientific Content
  - Need revision. Mandatory, one-on-one writing instruction is preferable.
  - In-class instruction is insufficient

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Based on Lessons Learned, We Defined Formal Program Structure

- Students receive writing instruction in lecture
- Handouts help students to develop their skills and guide their writing
- First-drafts of papers sent to writing assistants and to course TA's
- Writing assistants make comments on drafts and return to students, Course TA's grade the technical merits of the first drafts
- Students read comments and then conference with their writing assistant
- Final drafts, based on comments and the conference, are submitted to the writing assistants

An unexpected challenge: Orchestrating delivery of feedback and grading on technical aspects of papers and on writing.

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Year 2 (2010-11) Assignment Sequence: Follows Rhetorical Logic of Scientific Communication

- Assignment order guided by the **scientific content** (IMRDC)
- Meetings with writing assistants now **mandatory**
- Brief **handouts** distributed to complement in-class instruction
- Same assignments as previous years
- No substantive change in writing "effort" (~**20** hours, ~**45** pages)

(**–5** pages)

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Cumulative Lessons Learned

- Year 1 – Follows Conceptual Logic of the Scientific Content
  - Need mandatory, one-on-one writing instruction
  - In-class instruction is insufficient
- Year 2 – Follows Rhetorical Logic of Scientific Communication
  - Need to help students learn how to write like scientists instead of students
  - Need to provide explicit instruction in “skills” of science writing

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Year 3 (2011-12) Assignment Sequence: Follows Craft Logic of Scientific Practice

- Training manual developed based on WA questions and comments
- Skills-based ("**craft**") assignments:
  - Presenting data in tables, figures, and equations
  - Finding resources and sources: library skills workshop
  - Fleshing-out ideas with outlines
- Framing the writing exercises in terms of **relevant** scientific pursuit (motivation vs. objective vs. pedagogic purpose)
- Order of assignments unchanged (IMRDC)
- Same writing effort leads to less pages (~20 hours, ~35 pages)
  (**–15** pages)

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Cumulative Lessons Learned

- Year 1 – Follows Conceptual Logic of the Scientific Content
  - Need mandatory, one-on-one writing instruction
  - In-class instruction is insufficient
- Year 2 – Follows Rhetorical Logic of Scientific Communication
  - Need to help students learn how to write like scientists instead of students
  - Need to provide explicit instruction in “skills” of science writing
- Year 3 – Follows Craft Logic of Scientific Practice
  - FY students have difficulty putting themselves in the role of a scientist
  - “Use it or lose it”: Students need to revisit old material

Year 4 (2012/13) Assignment Sequence: Follows Multiple Logics, Just-In-Time Learning

- Less is more – students do not write **unnecessary** assignments
- Order of assignments reflects a **just-in-time** learning approach
  - Making students write whole papers leads to practicing bad habits
  - Novices have little/no context for understanding "Experimental" or "Introduction" sections
  - Novices **can** relate to "Results and Discussion"
- Explicit instruction on the **form** and **language** of scientific writing
- Later assignments make **explicit reference** to prior work and learning
- Substantial increases in student learning outcomes, substantial reduction in student output (~10-15 hours, ~15 pages)

(**–5** hours, **–5** pages)

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Cumulative Lessons Learned

- Year 1 – Follows Conceptual Logic of the Scientific Content
  - Need mandatory, one-on-one writing instruction
  - In-class instruction is insufficient
- Year 2 – Follows Rhetorical Logic of Scientific Communication
  - Need to help students learn how to write like scientists instead of students
  - Need to provide explicit instruction in "skills" of science writing
- Year 3 – Follows Craft Logic of Scientific Practice
  - FY students have difficulty putting themselves in the role of a scientist
  - "Use it or lose it": Students need to revisit old material
- Year 4 – Follows Multiple Logics, Just-In-Time Learning
  - Successes: less is more, just-in-time, and focus on student-accessible skills
  - Failures: - well-formatted papers still suffer from lack of coherence,
- arguments are still very novice
- students approach the literature as an afterthought, not a resource

BEAM to the rescue

BEAT: Functional Terms for Sources and Data

Background, Exhibits, Arguments, Methods/Theory

Background Sources	Materials whose claims a writer accepts as grounding facts and expects readers to accept as grounding facts.
Exhibits or Exhibit Sources	Materials a writer offers for explication, analysis, or interpretation.
Arguments or Argument Sources	Materials whose claims a writer affirms, disputes, refines, or extends in some way.
Method or Theory Sources	Materials from which a writer derives a governing concept or a manner of working.

My Argument: These terms provide a framework that helps students understand and play the "disciplinary argument" game.

- Framework for identifying and analyzing the ways writers use sources in academic arguments
- Framework for understanding similarities/differences between arguments in different disciplinary contexts

Year 5 (2013/14) Assignment Sequence: Engaging with sources to craft strong papers

- Continued with successful logics: craft logic, less is more, and just-in-time
- Refocused on the use of the literature
- Scientists generate ***exhibits*** – science writing starts by engaging with them: What exhibits are useful? not useful? (Figures, tables)
- Results are not just the data/exhibits. Results must engage in an ***argument*** with the field. Are their results affirming? Disputing? Refining?
- Understanding and presenting results requires an understanding of the ***theory*** and ***methods*** of the chemistry
- This is how ***expert scientists*** think about their results – our job is to get these students to start seeing their work in the same way.

- Incredible result: student effort remains ~**20** hours
  output is concise (~**7** pgs final product, ~**20** pgs workflow)

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Conclusions: Major Outcomes

Major Outcomes

- Students approach writing in the sciences with maturity
- Students spend time understanding their results and researching the implications
- Students do *not* waste time on lengthy, ill-conceived work
- Student learning of science concepts augmented by research in the literature and preparation of manuscripts
- Writing is viewed as the logical culmination of scientific work
- Increased rate of funded undergraduate research proposals, group presentations, and posters

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Conclusions: Beliefs and Questions

What We Believe

- Sequence must be consistent with multiple logics:
  - conceptual logic of the scientific subject
  - rhetorical logic of scientific communication
  - craft logic of scientific thinking
- Less is more.
- Teaching real forms of science writing is most effective.
- "Just in Time" teaching/learning is most effective.
- Make no presuppositions of prior understanding about chemistry or writing.
- Focus on engaging with sources is key to

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Conclusions: Beliefs and Questions

Open Questions

- How do we ensure consistency of interactions with writing assistants?
- How should content and writing be weighted in grading?
- What metrics can we use to assess retention of learning and transfer to other chemistry courses?
- How can department achieve vertical integration in chemistry curriculum?
- How does department reach chemistry students who *do not* take the writing-intensive intro sequence?
- Can this model be used effectively without *writing assistants*?

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Conclusions: Future directions

Horizontal expansion plans: CH109/110

- Enable us to more uniformly reach our chemistry majors
- Identical course structure and similar labs
- Major challenge: enrollment is 150-180 students
- New division of labor for writing instruction, feedback, and assessment.

Vertical expansion plans: upper-division courses

- Reinforce lessons, skills learned in freshmen courses
- Expand skill-sets as students progress from novices to experts
- Introduce students to additional genre-specific conventions and forms

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- Joseph Bizup (Director, CAS Writing Program)
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- Seann Mulcahy
- All of the writing assistants

Enrollments, Staff, and Costs

	Year 0 08-09	Year 1 09-10	Year 2 10-11	Year 3 11-12	Year 4 12-13
Student enrollments	57/49	76/65	88/80	58/48	86/76
Number of WAs	-	5/4	9/8	6/5	9/8
Number of course TAs	2/2	2.5/2	2.5/2	3.5/2.5	4/3
Cost of program (total)	-	$ 4,000	$ 22,000	$15,000	$ 22,500
Cost (per student)	-	$ 28	$ 130	$ 142	$ 139
Total writing hours/ student	20/20	20/20	20/24	15/22	10/20
Approx. pages of writing	55/50	55/50	45/45	25/35	15/30

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"Writing is the final step in the scientific process."

--Binyomin Abrams, 2009

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Intrinsic Connection Between Doing Science and Writing Science

When all the students in the class obtain the same results to an activity, and there is only one scientifically acceptable outcome, the learners quickly realize that they must somehow generate, copy, or paraphrase the knowledge claim that is desired by the teacher. Thus, writing in this genre can easily become a rote activity, especially when the students have no opportunity to determine the appropriate methods for the investigation, ways to display the data, or new meanings for the data.

--Carolyn Keys. "Revitalizing Instruction in Scientific Genres: Connecting Knowledge Production with Writing to Learn in Science." *Science Education* 83 (1999).

[I]t may be helpful to understand disciplinary ways of doing and the connection to knowing and writing by looking at an illustration of a concrete form of doing: laboratory experiments. A lab experiment is designed to engage students in a particular way of doing by which they will learn about the scientific concept of the lab and also how to apply an empirical mode of reasoning about the physical world. Thus, the lab experience is a way of doing that is directed toward a way of knowing. It is primarily in writing the lab report, however, that doing becomes knowing. . . . It provides an opportunity for students to reflect on the relationship between the lab and the scientific concept of the lab and to frame the doing of the lab in the structure of scientific reasoning.

--Michael Carter. "Ways of Knowing, Doing, and Writing in the Disciplines." *CCC* 58.3 (2007).

In our view, successful inquiry-based writing requires three modifications to the inquiry lab. First, lab courses should give students practice in forms of writing actually used by scientists. Second, writing tasks must be aligned with the activity of the lab so that students have something meaningful to say. And third, student writing must have a real audience.

--Cary Moskovitz, David Kellogg. "Inquiry-Based Writing in the Laboratory Course." *Science* 332 (20 May 2011).

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Multiple Considerations and Challenges to Developing and Implementing a Writing-Intensive Chemistry Class

Pedagogical

- Need to theorize relationship among learning goals: content instruction, mastery of laboratory techniques, and writing
- What *principles* should govern pedagogy and assignment sequence?

Institutional and Curricular

- Who "owns" the course?
- What is the relationship to the first-year writing requirement (2-sem sequence of writing seminars)?
- What will CH111/112 "count" for?
- What is the relationship to other chemistry courses?

Disciplinary: pieties, provincialisms, and skepticisms

- Scientists: "Do we (you) *really* care about writing, like we say we do?"
- Humanists: "Are they (you) *really* qualified to teach writing, as we are?" "Will *it* (the class, the writing) look like what I teach?"

Practical

- Scale?
- Workload for students, teachers?
- Staffing and division of labor?
- Funding?
- Sustainability?

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CH111/CH112 Course Structure

Standard, honors-level first-year chemistry course sequence

- 4 credits per course
- Lecture (3 hrs), discussion (1 hr), pre-lab lecture (1 hr), and lab (4 hrs)
- Students take WR100/WR150 (required first-year writing courses) concurrently
- "Track-skipping" forbidden (into parallel intro-chem courses 101/102, 109/110)

Types of assignments in lab portion of the course

- Post-lab questions (5 in fall, 2 in spring)
- Formal lab reports (5 in fall, 4 in spring)
- Capstone project (team-based research project in spring semester)
  - Total assignments in fall: 10
  - Total assignments in spring: 6 + Capstone project

Staffing Structure and Division of Labor

Issues we considered when designing staffing structure:

- Solitary teacher (humanities model) won't work
- Inconsistent enrollments semester to semester, year to year
- Scaling instruction to large lecture/lab course
- Supply of potential qualified Writing Assistants

To address these issues, we relied on a division of labor among instructors:

- Course Instructor: Full-time Lecturer in Chemistry
  Hiring, training, and content creation
- Writing Assistants: Graduate students in science fields (Chem and others)
  Confer with students; comment on, grade writing
- Teaching Assistants: Graduate students in Chemistry
  Grade papers on technical merits
- Writing Consultant: Full-Time Lecturer in Writing Program
  Provide advice on writing pedagogy, assist CI
  in training WA's, contribute to prep of writing manual

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Enrollments, Staff, and Costs

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