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

Binyomin Abrams
Senior Lecturer, Department of Chemistry
abramsb@bu.edu

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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, 4 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
- Teaching Assistants: Graduate students in Chemistry; Grade papers on technical merits
- Writing Assistants: Graduate students in science fields (CH and others); Confer with students; comment on, grade writing

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Timeline of Development and Implementation

Year 0 – Baseline
- Formal lab reports for every other lab (5 per semester, including 1st)
- Students receive a five-page "Basic Guide to Writing Lab Reports"
- No explicit, in-class writing instruction
- ~**20** hours of writing, ~**50** pages per student/semester

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Timeline of Development and Implementation

Year 0 – Baseline
- ~**20** hours of writing, ~**50** pages per student/semester

Year 1 – No logic / Writing instruction as an afterthought
- In-class instruction and optional writing tutoring
- No change in work, No change in outcomes
- Changes for next year: handouts and schedule for revisions

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Timeline of Development and Implementation

Year 0 – Baseline
- ~**20** hours of writing, ~**50** pages per student/semester

Year 1 – No logic / Writing instruction as an afterthought
- In-class instruction and optional writing tutoring

Year 2 – Rhetorical logic of Scientific Communication
- Writing assistant role is cemented. Handouts are provided.
- Instruction follows the sequence of the rhetoric discourse.
- Student anxiety increases, but writing remains juvenile
- Changes for next year: direct instruction of craft skills (figures, literature, outlines)

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Timeline of Development and Implementation

Year 0 – Baseline
- ~**20** hours of writing, ~**50** pages per student/semester

Year 1 – No logic / Writing instruction as an afterthought
- In-class instruction and optional writing tutoring

Year 2 – Rhetorical logic of Scientific Communication
- Writing assistant role is cemented. Handouts are provided.
- Instruction follows the sequence of the rhetoric discourse.

Year 3 – Craft logic of Scientific Practice and Communication
- Craft skills taught first: exhibits (figures/tables), outlines, and literature
- Remaining instruction follows the sequence of the rhetoric discourse
- Polished, shorter papers (looks polished); still juvenile (no change in critical thinking)
- Student anxiety maximum, despite decrease in page production (35 pgs)
- Changes for next year: rethink sequence of assignments, focus on "meaning"

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Timeline of Development and Implementation

Year 0 – Baseline
- ~**20** hours of writing, ~**50** pages per student/semester

Year 1 – No logic / Writing instruction as an afterthought
- In-class instruction and optional writing tutoring

Year 2 – Rhetorical logic of Scientific Communication
- Writing assistant role is cemented. Handouts are provided.
- Instruction follows the sequence of the rhetoric discourse.

Year 3 – Craft logic of Scientific Practice and Communication
- Craft skills then IMRD sequence
- Polished, shorter papers (looks polished); still juvenile (no change in critical thinking)

Year 4 – Less-is-more, Just-in-time logics added (Multiple logics)
- New sequence: craft skills, RDC papers, Methods/Introduction when relevant
- Less juvenile (no irrelevant Introductions and Methods sections)
- Lowest anxiety level since baseline (decrease in time and pages: 15 hrs, 15 pgs)

➢ Overall argument in paper remains superficial and novice.
➢ Then, 2013 CCCC..

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Year 5 – Nature of science logic / Engaging with exhibits and sources as practitioners of science

- Continued with successful logics: craft logic, less is more, and just-in-time
- 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?
- Refocused on the use of the literature as practitioners of science
- 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.
- Voice, tenses, conventions, and structure are a ***veneer*** on top of the science.
- Incredible result: student effort remains ~**20** hours
  output is concise (~**7** pgs final product, ~**20** pgs workflow)

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Developed Metrics for Scholarly Research-Based Writing

(A) Critical thinking / Interpretation of results

1) Raw data as "results"
2) Makes observation of data in prose
3) Any discussion of "correctness" of result (accuracy, etc…)
4) Appropriate discussion of "correctness"
5) Science behind the result is discussed (limits, applicability,…)
6) Links results to motivation and impacts
7) True motivation, true impacts

(B) Research and Engagement

1) Didn't understand the result
2) Used pre-lab, lab manual, lecture, and course text for background
3) Looked for *any* result *anywhere* to match results
4) Found a reputable / primary source to match the results
5) Surveyed the literature for appropriate source to contrast
6) Researched to determine the reason for their result, not just a source that is similar

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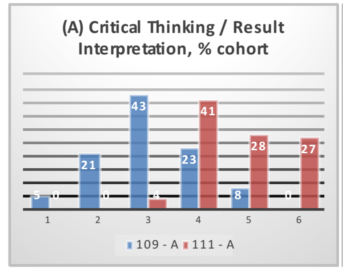
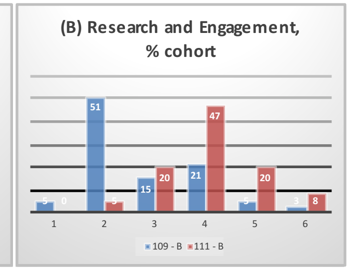
Major gains in rubric metrics

Cohort	(A) Critical thinking / Result Interpretation	(B) Research and Engagement
Incoming students	~ 2	~ 2
Post "Year 0" CH111	3 – 4	3
Post "Year 5" CH111	4.8 ± 0.9	4.0 ± 1.0
Post CH109 students	3.0 ± 1.0	2.8 ± 1.2





Significant shifts in students attitudes

Attitude	Before CH111	After CH112
Understand importance of writing in science	3.0 ± 1.0	4.7 ± 0.5
Scientists write in complicated/obtuse way	4.0 ± 0.8	1.9 ± 0.8
Feel prepared to write science papers	2.1 ± 0.9	4.4 ± 0.5

Student feelings about program components

Question about program	Response
Despite being more work, do it again?	4.6 ± 0.7
Necessity of program documents	4.3 ± 0.7
Usefulness of writing assistant	4.3 ± 0.9

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Major Conclusions – What we believe

- No assumptions about "craft" abilities. ***Teach everything***.
- Do *not* waste time ill-conceived work. ***Less is more, Just-in-time***
- Focus on nature of science and crafting ***strong arguments*** leads to writing in the sciences with maturity
- Writing must be ***preceded*** by instruction in critical thinking
- Students must ***engage with sources*** as part of process of science
- Structure and conventions should taught ***in context*** of argument

Major Outcomes

- ***Content Knowledge Gains*** achieved without explicit goals stated
- Major ***shift in attitudes*** about the nature of science and writing
- Increased rate of funded undergraduate research proposals
- ***ESL students thrive*** as well as native speakers in this program.

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Acknowledgments

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

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ESL student success in BUCWP

- ESL students succeeded as well as native speakers on all measures except for language

Cohort	(A) Crit. Res.	(B) Research	Organization	Language	Argument
CH111	4.8 ± 0.9	4.0 ± 1.0	3.6 ± 0.6	5.2 ± 0.9	3.4 ± 1.1
CH109	3.0 ± 1.0	2.8 ± 1.2	3.1 ± 0.6	4.6 ± 0.8	2.7 ± 0.9
ESL-111	4.5	4.0	3.0	4.0	3.5

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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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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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