ACS Guidelines (section 7): Development of Student Skills

“In order to prepare students to enter the workforce ... programs must provide experiences that go beyond chemistry content knowledge ... to develop competence in other critical skills necessary for a professional chemist.”

- Chemical Literature and Information Management skills (7.2)
- Communication skills (7.4)

“[...] either dedicated courses or integration of learning opportunities throughout the curriculum can be used to develop and assess student skills.”

1. Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor’s Degree Programs. Spring 2015 (ACS Committee on Professional Training)
BU Hub: Communication learning outcomes

To thrive as citizens of the contemporary world, we all need the capacity to communicate effectively … **writing remains the foundation**.

By graduation, all students will be able to communicate effectively … special proficiency in those forms of communication **most relevant to their particular majors or prospective professions**.

1. Students will be able to craft responsible, considered, and well-structured written arguments…
2. Students will be able to read with understanding, engagement, appreciation, and critical judgment.
3. Students will be able to write clearly and coherently in a range of genres and styles, integrating graphic and multimedia elements as appropriate.

Addressing concerns about teaching writing in chemistry

- **Fixed pie** fallacy
- Successful **translation**
- Qualified instructors
- International and ESL students
What we know about teaching writing in the disciplines

- Simulations don’t work - (scientists) need something meaningful to write\(^2,3\)
- Writing Across the Curriculum (WAC) – start early and build up\(^4\)
- Asking students to write without instruction leads to reinforcing problems

- Paper “structure” is easy (easier?) to teach
- Students developing a scientific “voice” is harder to achieve – takes time

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**CH WRITES: Integrated Chemistry Writing in Quant Labs**

**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 first-semester of the course

**Types of assignments in lab portion of the course**
- Data analysis and thought-provoking questions (50%)
- Writing and Information Literacy assignments (50%)
- Capstone project (team-based, semester-long research project in spring semester)

**Division of instructional labor**
- Course Instructor: content instruction, course design, assignment
- Graduate TA’s: practice and skills instruction, evaluate conceptual post-lab assignments
- Undergraduate Learning Assistants: peer mentors and lab support
- Writing Fellows: mentor students writing/argumentation/literacy skills, one-on-one instruction
CH WRITES: Development of the program

We made mistakes. A lot of mistakes ...

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
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

**Year 2 – Rhetorical logic of Scientific Communication**
- Writing Fellow role is cemented. Handouts are provided.
- Instruction follows the sequence of the rhetorical discourse (Intro → Conclusion).
- Significant improvement in quality of form, voice of papers
- Student anxiety increases, but writing remains juvenile
- Changes for next year: direct instruction of craft skills (figures, literature, outlines)
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 (Intro → Conclusion)
- 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”

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...
  - Year 5 starts the program as it exists now
Integrating Research-based Writing into First-Year Chemistry Courses

Year 5 – Nature of science logic / Structured development of science literacy and writing

- 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?
- Analyzing, presenting, and communicating results requires a deep understanding of the *theory* and *methods* of the chemistry
- Refocused on the use of the *literature* as practitioners of science
- 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 (necessary) *veneer* on top of the science

Assessment Rubrics for Scholarly, Research-Based Writing

**(A) Research and Info Literacy**

1) Did not understand results
2) Used *instructor-provided* info, or Found *any* source to match
3) Found a *reputable* source to match
4) A *survey* of the literature for match or contrast of their work
5) True motivation, true impacts

**(B) Argument and paper logic**

Novice
1) Argument is not sound
2) Erroneous or irrelevant claims make argument weak, unfocused, or circular
3) Logical argument, but lacks strength

Expert-like
4) Well-supported argument that is persuasive
5) Presentation of the argument is well-ordered, articulated, and written
Substantial gains in literacy, argument, and writing

<table>
<thead>
<tr>
<th>Cohort</th>
<th>(A) Research and Info. Literacy</th>
<th>(B) Argument and Paper Logic</th>
<th>(C) Voice, Organiz., and Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming students</td>
<td>1 – 2</td>
<td>1 – 2</td>
<td>1 – 2</td>
</tr>
<tr>
<td>CH109/110</td>
<td>1.8 ± 1.3</td>
<td>2.4 ± 1.2</td>
<td>3.8 ± 0.7</td>
</tr>
<tr>
<td>“Year 5” CH111</td>
<td>3.0 ± 1.0</td>
<td>3.8 ± 0.9</td>
<td>4.0 ± 0.8</td>
</tr>
<tr>
<td>&quot;Year 10” CH111</td>
<td>3.8 ± 0.8</td>
<td>3.9 ± 0.9</td>
<td>3.9 ± 0.7</td>
</tr>
</tbody>
</table>

- **Significant gains** across the board
- Year 6+: added emphasis on literature, bibliographies, and collaboration
- ESL students show *no significant difference* in (A) or (B)
- Incredible result: student effort remains 20 hours/semester
  output is focused (10 pgs final product, 20 pgs workflow)
Integrating Research-based Writing into First-Year Chemistry Courses

Shifts in students attitude about writing in chemistry

Nature of Writing in the Sciences

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand importance of writing in science</td>
<td>3.0 ± 1.0</td>
<td>4.7 ± 0.5</td>
</tr>
<tr>
<td>Scientists write in complicated/obtuse way</td>
<td>4.0 ± 0.8</td>
<td>1.9 ± 0.8</td>
</tr>
<tr>
<td>Feel prepared to write science papers</td>
<td>2.1 ± 0.9</td>
<td>4.4 ± 0.5</td>
</tr>
</tbody>
</table>

Student feelings about the integrated writing program

<table>
<thead>
<tr>
<th>Question about program</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Despite being more work, do it again?</td>
<td>4.6 ± 0.7</td>
</tr>
<tr>
<td>Necessity of program documents</td>
<td>4.3 ± 0.7</td>
</tr>
<tr>
<td>Usefulness of writing assistant</td>
<td>4.3 ± 0.9</td>
</tr>
</tbody>
</table>

Major Conclusions – What we believe

- Focus on nature of science and crafting *strong arguments* leads to writing 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 be 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
- Significant gains are achieved through *in-class workshops* even without writing fellows
- Increased rate of funded undergraduate research proposals
- *ESL students thrive* as well as native speakers in this type of instruction.
- WAC instruction has *programmatic impact* and improved *graduate student education*
Horizontal expansion plans: CH109/110

- Major challenge: enrollment is 150-180 students
- Enable us to more uniformly reach our chemistry majors
- Identical course structure, some similar labs
- New division of labor for writing instruction, feedback, and assessment (i.e., no WFs)

No writing fellows? No problem! (somewhat)

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<th>(C) Voice, Organiz., and Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH109 – Year 5</td>
<td>1.8 ± 1.3</td>
<td>2.4 ± 1.2</td>
<td>3.8 ± 0.7</td>
</tr>
<tr>
<td>CH109 – Year 10</td>
<td>3.4 ± 1.2</td>
<td>3.2 ± 1.0</td>
<td>3.1 ± 0.9</td>
</tr>
</tbody>
</table>

- Writing instruction for CH109 during *in-lab workshops* with GTAs and LAs
Horizontal expansion plans: CH109/110 (Complete)

- Major challenge: enrollment is 150-180 students
- Enable us to more uniformly reach our chemistry majors
- Identical course structure, some similar labs
- New division of labor for writing instruction, feedback, and assessment (i.e., no WFs)

Vertical expansion plans: upper-division CH courses

- Reinforce lessons, skills learned in first-year courses (Writing Intensive Courses; BU Hub)
- Expand skill-sets as students progress from novices to experts
- Introduce students to additional genre-specific conventions and forms (Oral, MM)

Collaborations with other disciplines

- Searching for collaborations with other disciplines...

Acknowledgments

- Joseph Bizup (Associate Dean, former director of CAS Writing Program)
- Sandy Zhang (Graduate student)
- Seann Mulcahy (Post-doc, now at Providence College)
- Rebecca Kinraide (CAS WP)
- All of the writing fellows

Details about writing program and assignments: people.bu.edu/abramsb/research/
ESL students succeed in BU WRITES program

<table>
<thead>
<tr>
<th>Cohort</th>
<th>(A) Research</th>
<th>(B) Argument</th>
<th>(C) Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH111</td>
<td>3.8 ± 0.8</td>
<td>3.9 ± 0.9</td>
<td>3.9 ± 0.7</td>
</tr>
<tr>
<td>CH109</td>
<td>2.0 ± 1.2</td>
<td>2.4 ± 1.1</td>
<td>3.8 ± 0.7</td>
</tr>
<tr>
<td>ESL-111</td>
<td>4.0</td>
<td>4.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

- ESL students in the BU WRITES program (CH111) succeeded as well as native speakers on all measures except for language (a component of the paper grade)

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?