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.”
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\(^1,2\)
- Writing Across the Curriculum (WAC) – *start early* and build up\(^3\)
- 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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\(^3\) S. McLeod. “Defining Writing Across the Curriculum.” *Writing Program Administration* 1987, 11 (1), 19
BU 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

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.
### 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) *Survey* of literature for match or contrast of their work  
5) True motivation, true impacts  

**(B) Argument and paper logic**

1) Argument is not sound  
2) Erroneous or irrelevant claims make argument weak, unfocused, or circular  
3) Logical argument, but lacks strength  
4) Well-supported argument that is persuasive  
5) Presentation of the argument is well-ordered, articulated, and written

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### 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>- -</td>
</tr>
<tr>
<td>CH109 Course</td>
<td>2.0 ± 1.2</td>
<td>2.4 ± 1.1</td>
<td>3.8 ± 0.7</td>
</tr>
<tr>
<td>&quot;Year 5&quot; 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)
Substantial gains in literacy, argument, and writing

![Bar charts showing gains in literacy and argument](image)

Shifts in students attitude about writing in chemistry

<table>
<thead>
<tr>
<th>Nature of Writing in the Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitude</strong></td>
</tr>
<tr>
<td>Understand importance of writing in science</td>
</tr>
<tr>
<td>Scientists write in complicated/obtuse way</td>
</tr>
<tr>
<td>Feel prepared to write science papers</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>
No writing fellows? No problem! (mostly)

<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>CH109 – Year 5</td>
<td>2.0 ± 1.2</td>
<td>2.4 ± 1.1</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

![Graphs showing Rubric Scores for (A) Research and Information Literacy and (B) Argument and Paper Logic](image)

**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 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*
Acknowledgments

- Joseph Bizup (Director, 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>1.8 ± 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)