Survey of Ph.D. Recipients in Chemistry*

The primary objective of the Committee on Professional Training (CPT) is to facilitate the maintenance and improvement of the quality of chemical education at the postsecondary level. The ACS approval program for undergraduate programs in chemistry is well known, but CPT also publishes data on graduate education in chemistry. In the context, in 2015 CPT surveyed recipients of the Ph.D. degree to seek their opinions and advice about their experiences in U.S. graduate programs. This followed a similar survey fielded by CPT in 1998: http://www.acs.org/content/dam/acsorg/about/governance/committees/training/reports/cptreports/graduate-education-in-chemistry.pdf.

The questionnaire was sent by email to 4000 randomly selected ACS members who have Ph.D. degrees. Two cohorts were surveyed, 2000 from each cohort: Those age 33 to 37 and those 43 to 47. The purpose here was to detect any differences in attitude and training between those who received the Ph.D. degree at different times. The response rate was rather low (~14%), even after a reminder email, so the survey was sent to another 2000 from each cohort. In total, responses were received from 1104 people (13.8%), 784 of whom obtained their Ph.D. in the U.S. Of the 784 responses which were used in the analysis, 32.9% were from industry, 46.0% from academia, and 8.3% from government; the remainder were "other" or unidentified. Female respondents comprised 35.3% of the total. (Note: Current ACS membership is 54% industry, 36% academia, and 29% female.)

Respondent Breakdown Age	
30s Cohort	443
40s Cohort	341

Respondent Breakdown	
Industry	32.9%
Academia	46.0%
Government	8.3%

The survey consisted of 28 questions related to the graduate school experience/requirements and advisor interactions. Most, but not all, questions made a statement and asked for a response from 1 (strongly agree) to 5 (strongly disagree); questions about the contributions of the research advisor to their education and overall training received asked for a response ranging from 1 (excellent) to 5 (poor). Thus, a low average numerical response indicated a generally favorable impression of that aspect of graduate education. The average of answers ran from about 1.75 to 3.50, indicating a general satisfaction with the graduate experience. For purposes of analysis, answers to questions that averaged <2.25 are taken as positive, 2.25 to 2.50 as relatively neutral, and >2.50 as negative. In addition to answering the 28 questions in the survey, 50% of respondents gave written comments expounding on their graduate-school experience. Representative comments are included in the analyses of results, below.

It is important to bear in mind that 86% of those who received the email survey did not respond and there is no way of knowing how their views would affect the average responses reported here. Importantly, industrial members of ACS are underrepresented among respondents. Nonetheless, we believe that the numerical results that were obtained will be of significant interest to the graduate-education community.

General results and average responses. Respondents agreed that their overall graduate experience prepared them for their ultimate career path (1.99), they were satisfied with their overall graduate experience (2.08), and they are using the skills and knowledge gained in their graduate program in their current job (1.84).

*This is an updated and expanded version of the report that appeared in the Fall, 2015, Newsletter of the Committee on Professional Training

General Satisfaction	Average Response
Graduate experience prepared for career path	1.99
Satisfied with their overall graduate experience	2.08
Using the skills and knowledge gained	1.84

Those who were required to create an original research proposal (68% of respondents) thought this was valuable (1.84). Many who did not have this requirement wish they had: "*We were not required to write an original research proposal as part of our Ph.D. training. This was an utter disservice to our future careers*." Taking a comprehensive written exam (28% of respondents) was viewed as less valuable (2.29), as was taking cumulative exams (61% of respondents, 2.50). Viewed as valuable were giving formal presentations (1.85), serving as a TA (2.09), and attending seminars (2.21). The 65% of respondents who described their graduate research as interdisciplinary viewed this positively (1.99). As one respondent put it, "*Graduate programs should include more interdisciplinary education, especially for students interested in careers in industry*." Additional coursework in chemistry was not viewed as necessary (2.90), but additional courses outside of chemistry would have been more welcomed (2.38), especially by respondents in industry (2.19): "*I really would have benefited from some engineering courses that would have imparted some business skills*."

Value of Components of Graduate Education	Average Response
Taking a comprehensive written exam	2.29
Taking cumulative exams	2.50
Giving formal presentations	1.85
Serving as a TA	2.09
Attending seminars	2.21
Participating in interdisciplinary research	1.99
More coursework in chemistry would have been beneficial	2.90
Courses outside of chemistry would have been beneficial	2.38

Skill training during the graduate program (formal or otherwise) was rated well in general (e.g., oral and written communication, use of the chemical literature, ethical conduct of research, use of appropriate technology tools), except for laboratory safety (2.48), teaching (2.52), and proposal writing (3.04). In fact, a large number of respondents indicated that they would have profited from "*more preparation for applying for grants*."

Satisfaction with Training During the Graduate Program	Average Response
Oral communication	2.02
Written communication	2.09
Use of chemical literature	1.89
Ethical conduct of research	2.05
Use of appropriate technology tools	2.23
Laboratory Safety	2.48
Teaching	2.52
Proposal writing	3.04

The overall effectiveness of the graduate advisor was well rated (2.11), including for mentoring (2.08), but not for providing career advice (2.90).

Satisfaction with Graduate Advisor	Average Response
Overall effectiveness of the graduate advisor	2.11
Mentoring	2.08
Providing career advice	2.90

More often than not "*advisors had no knowledge of any career paths outside of academia*." Similarly, respondents said that in graduate school overall, beyond interactions with their advisor, they did not receive sufficient career counseling to understand career options (3.36). Nor did they find their faculty advisory committee particularly helpful (2.56): "*[We] only saw our committee at our defenses*." Respondents were generally satisfied with the level of financial support they received throughout graduate school (2.08). The vast majority (94%) of respondents spent at least some time as a TA. The median percentage of total support as a TA was 30%; the mean was 37% and the mode was 20% of total support.

A key culminating question, "If I had it to do over, I would pursue an advanced degree in chemistry," received an average score of 2.01. However, 18% of respondents disagreed somewhat or strongly with this statement (see discussion below, industry vs. academia).

If I had it to do over, I would pursue an advanced degree in chemistry.

Rating	30s Cohort	40s Cohort
1	232	198
2	66	39
3	54	33
4	26	30
5	49	31
N/A	13	9

Differences in responses by those employed in industry compared to those in academia. While the groups were equally satisfied with their overall graduate experience (2.01 for academics, 2.05 for industrial folks), differences exist between these two groups more often than not. This is the same pattern seen in the 1998 survey, where it was concluded that "…these results support the frequently expressed view that our Ph.D. programs are not preparing individuals for employment in industry as effectively as they should." The bottom line is that academicians were in greater agreement that their graduate experience prepared them for their ultimate career path (1.86 vs. 2.08). However, even for those going into teaching, their graduate education could have been enhanced: "*I would argue that, generally speaking, we're only preparing those people for the research side of academia and not for the teaching side*." From another respondent: "*I think there should be more opportunities within graduate school for learning about being a successful educator. I would like to have been given the opportunity to learn about writing exams, learning strategies, building courses, etc*."

Career counseling in graduate school got poor marks from both groups, though worse from industry folks (3.61) than academicians (3.23). This related closely to career advice from their advisor: a surprisingly poor 2.74 for academics, 3.12 for those in industry.

Career Counseling in Graduate School	Average Response
Industry	3.61
Academia	3.23

Career Advice from Advisor	Average Response
Industry	3.12
Academia	2.74

Safety training in the graduate program was viewed as worse by those in industry (2.73) compared to academics (2.34).

Safety training	
Industry	2.73
Academia	2.34

Particularly troubling was the comment: "*We were tacitly required to do things in grad school that would result in immediate termination in most industrial labs*." A glimmer of hope on the safety front is the fact that the 30's cohort viewed safety training as a little better than the 40's cohort: 2.67 vs. 2.81 for those in industry, 2.29 vs. 2.40 for those in academia.

Training Received in Laboratory safety

Rating	30s Cohort	40s Cohort
1	117	73
2	137	99
3	95	97
4	60	51
5	31	20

Perhaps the most striking difference between these two groups was their answers to whether they would again chose to pursue a Ph.D. Academicians rated this 1.73 (68% agreed strongly, 12% disagreed somewhat or strongly), while industrial folks were less sure, at 2.19 (49% agreed strongly, 21% disagreed somewhat or strongly). A typical response by someone who would not again chose to pursue a Ph.D.: "*Though my experience was good, I felt that my graduate program didn't prepare me for the real world*."

Differences in responses by gender. Overall, there were few differences in responses between men and women. Females (35.3% of the total) made up 26.2% of industrial respondents and 42.8% of academicians. Thus, gender and academic vs. industrial employment are not independent variables. That said, women were more likely than men to be encouraged to attend and participate in professional meetings while in graduate school (1.96 vs. 2.17) and had a somewhat better view of their communication training (oral, 1.92 vs. 2.07; written, 2.03 vs. 2.12). On the other hand, women were less likely to agree that their graduate experience prepared them for their ultimate career path: 2.06 vs. 1.94. This takes on added importance because academicians agreed with this statement much more so than industrial folks, 1.86 vs. 2.08. There were no differences between men and women in their interactions with their advisor.

Females Respondents	(35.3%)
Industry	26.20%
Academicians	42.80%

Other characteristics of respondents.

Respondents were requested to provide additional information about themselves. Some of these data are of general interest to Ph.D. programs in chemistry.

As mentioned earlier, 35% of respondents were female. This compares to 21% of ACS members who hold a Ph.D. being female, but is very reflective of the current percentage of Ph.D. recipients in chemistry being female. (In the eight-year period 2003 to 2010, 34.8% of Ph.D. recipients in chemistry were women: see National Science Foundation, National Center for Science and Engineering Statistics, *Doctorate Recipients from U.S. Universities: 2013*, December 2014, Table 15.)

Among all respondents, 77% completed their Ph.D. program at a public institution. In comparison, 64% of the respondents attended public institutions as undergraduates while 36% attended private schools; as undergraduates, 63% of respondents attended an institution which has a Ph.D. program in chemistry.

The average time required to complete the Ph.D. was 5.59 years for all respondents (5.55 years for the 30's cohort, 5.64 for the 40's cohort), significantly higher than the 5.06 years required for the respondents to the 1998 survey. Some students required significantly longer than average to complete their degree: 20% reported taking more than 6 years. This compares to 10% in the 1998 survey. Not knowing whether respondents to the current survey are representative of all Ph.D. recipients in the two cohorts, a definitive conclusion cannot be reached concerning a possible significant increase in time to degree over the past two decades.

Among respondents, 62% (63% of the 30's cohort, 60% of the 40's cohort) did a postdoc before starting a permanent job. Of those who did postdoctoral work, 20% of the 30's cohort and 27% of the 40's cohort did more than one postdoc. As expected, respondents in academia (68%) were much more likely to have done a postdoc than those in industry (50%).

Respondents were asked to report the field in which they did their graduate work and the specialty most closely related to their present employment. A summary of the results is given in the table.

Percent Reporting Present Employment

Field of Specialization	Percent Reporting Ph.D. in Field	Most Closely Related to the Field
Organic Chemistry	21.2	12.4
Physical Chemistry	13.6	7.7
Analytical Chemistry	12.4	11.2
Inorganic Chemistry	12.3	4.9
Biochemistry	7.3	7.9
Materials Science	5.4	7.6
Chemical Biology	4.9	3.5
Polymer Chemistry	4.7	5.1
Chemical Engineering	4.0	5.2
Computational Chemistry	3.8	2.6
Environmental Chemistry	2.7	3.1
Chemical Education	1.6	10.1
Agricultural/Food Chemistry	0.9	1.5
General Chemistry	0.5	4.2
Clinical Chemistry	0.0	1.0
Other Chemistry	2.1	2.4
Non-Chemistry	2.5	9.6

The data in the table indicate that two-thirds (66.7%) of the Ph.D. degrees held by the respondents were in the traditional subdivisions of chemistry: organic, physical, analytical, inorganic, and biochemistry. However, when the fields most closely related to the present job are examined, it can be seen that many organic, physical, and inorganic chemists have migrated away from the field of their degree. On the other hand, nearly 10% of respondents report that their present employment has taken them into non-chemistry areas. These areas include, *inter alia*, physics/biophysics, astronomy, bioinformatics, regulatory science, patent law, public policy, medical writing, project management, and university administration. **These results reinforce the conclusion that a broadly based education for Ph.D. chemists is important to allow them to move into different areas as opportunities arise.**

Respondents were asked about the primary way they connected with their first permanent position following their Ph.D. Nearly half (44%) did so by applying to an advertised position (online or otherwise). However, as can be seen in the table below, this varied greatly between academic (60%) and industrial (24%) positions. Networking through the Ph.D. or postdoctoral advisor, or through a friend/acquaintance, also played a major role for many respondents: academic position, 25%; industrial position, 44%; all respondents, 33%. Networking through a friend/acquaintance was especially effective for connecting with industrial jobs (24% of respondents). On the other hand, none of the respondents reported connecting with a permanent position through a Campus Career Office.

What was the primary way you connected with your first PERMANENT position following your Ph.D.?			
Result	**All Respondents* (%)**	**Academic Position (%)**	**Industrial Position (%)**
Application to an advertised opening (online or print)	44.2	59.7	24.4
Blind application to employer (no advertised opening)	3.8	3.9	5.0
Ph.D. Advisor	11.9	10.1	14.0
Postdoctoral Advisor	5.8	4.2	6.5
Friend/ Acquaintance	15.5	11.0	23.6
On-Campus	5.1	0.8	11.2
ACS Employment Clearinghouse	3.1	3.7	3.5
Other Employment Clearinghouse	2.6	2.5	3.5
Campus Career Office	0.0	0.0	0.0
Other	8.0	3.9	8.1

* "All Respondents" includes government and no-position-specified employees.

Conclusions. The results indicate a generally positive view of Ph.D. programs taken by the respondents. However, there are two major areas where improvement is needed: career counseling (for either academic or industrial careers) and safety training.

Typical of voluntary comments on career counseling: "*We received virtually no career counseling. Most people had no idea how to find a job.*" This was true for counseling from the advisor and from the graduate program in general. This is consistent with the results of the 2013 *ACS Graduate Student Survey* (students still in graduate school, http://www.acs.org/content/dam/acsorg/education/educators/reports/2013-ACS-Graduate-Student-Survey-Report.pdf), which found only 9.5% of students reported that their advisor provided **non-academic career information** to a "considerable extent," while 26.3% reported this behavior "not at all." For **academic careers**, the corresponding numbers were 14.7% for "considerable extent" and 15.2% for "not at all." In this context, it should be noted that an increasing number of graduate students are becoming aware of Individual Development Plans (IDP) as a tool for career planning. The Graduate and Postdoctoral Scholars Office of the ACS has developed a chemistry-specific IDP tool which is available online at ChemIDP.org.

For safety training, we can hope that an increased emphasis on laboratory safety at colleges and universities, resulting in part because of well-publicized academic laboratory accidents in recent years, will lead to significantly better ratings in this area of graduate training in future surveys. Hopefully, recent efforts by the ACS will facilitate these improvements in academic laboratory safety. See *Creating Safety Cultures in Academic Institutions: A Report of the Safety Culture Task Force of the ACS Committee on Chemical Safety,* at http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/academic-safety-culture-report-final-v2.pdf; also see *Advancing Graduate Education in the Chemical Sciences: Summary Report of an ACS Presidential Commission,* at http://www.acs.org/content/acs/en/about/governance/acs-presidential-commission-on-graduation-education-in-the-chemical-sciences.html).

Questions 1-28 **Note: Industry average followed by academic average**

1. The institution that granted my Ph.D. degree is located
2. My overall graduate experience prepared me for my ultimate career path. **2.08, 1.86**
3. The formal courses that I took in my Ph.D. program adequately prepared me for my present position. **2.70, 2.27**
4. I would have benefited from additional specialized courses in chemistry. **2.82, 2.87**
5. I would have benefited from additional courses in disciplines other than chemistry. **2.19, 2.50**
6. The seminars and colloquia that I attended during my Ph.D. studies contributed significantly to my education. **2.30, 2.10**
7. The formal presentations (excluding research group presentations and teaching) that I made during my graduate experience prepared me for my career. **1.88, 1.82**
8. Please answer ONE question (a or b).
8a. I was required to create and present/submit an original research proposal(s), independent from my dissertation project, and I believe that this experience contributed significantly to my graduate education. **1.81, 1.92**
8b. An original research proposal(s) independent from my dissertation project was not required, and I believe that I would have benefited from such an experience. **2.94, 2.77**
9. My experience as a teaching assistant (or other teaching activities) has helped me in the performance of my job. **2.33, 1.84**
10. Please respond to the ONE question (a, b or c) that best describes your experience with the interdisciplinary aspects of your graduate research.
10a. My graduate research involved a formal interdisciplinary program that included scientists from areas outside chemistry. This experience has proven to be beneficial to me in my professional career. **1.91, 1.81**
10b. My graduate research was interdisciplinary in nature but did not include formal interactions with scientists outside chemistry. I would have benefited from such interactions. **1.96, 2.24**
10c. My graduate research was focused within the traditionally defined boundaries of chemistry. This experience has adequately prepared me for my present position. **2.60, 2.25**
11. Please respond to the ONE question (a or b) most pertinent to the requirements of your Ph.D. degree.
11a. I was required to take cumulative examinations. These contributed significantly to my graduate education. **2.52, 2.44**
11b. I was not required to take cumulative examinations. I would have benefited from such a requirement. **3.71, 3.81**
12. Please respond to the ONE question (a or b) most pertinent to the requirement of your Ph.D. degree.
12a. I was required to take a comprehensive written examination. This was an important component of my graduate education. **2.18, 2.29**
12b. I was not required to take a comprehensive written examination. I would have benefited from such a requirement. **3.87, 3.75**
13. Please respond to the ONE question (a or b) most pertinent to the requirements of your Ph.D. degree.
13a. I was required to take an oral examination prior to my thesis defense. This was beneficial to my graduate education. **2.00, 1.79**
13b. I was not required to take an oral examination prior to my thesis defense. I would have benefited from such a requirement. **3.52, 3.40**
14. The faculty advisory committee that monitored my progress toward the Ph.D. was constructive and helpful. **2.64, 2.53**
15. I received sufficient career counseling in graduate school to help me understand my career options and choose a career path. **3.61, 3.23**
Questions 16 through 19 ask for a response from 1 (excellent) to 5 (poor).
16. Please rate the contributions of your research advisor to your graduate education in the following areas:
a. Mentoring (e.g., role modeling, enthusiasm, work ethic, etc.) **2.09, 1.99**
b. Providing career advice **3.12, 2.74**

c. Providing feedback on progress towards the degree **2.50, 2.28**
d. Establishing appropriate standards (scientific, ethical) **1.79, 1.74**
e. Developing your problem-solving skills and the ability to plan/execute research **1.88, 1.91**
f. Increasing your scientific knowledge (relevant, up-to-date) **1.82, 1.75**
g. How would you rate the overall effectiveness of your graduate research advisor? **2.09, 2.03**
17. Please rate the training (formal or otherwise) you received during your graduate education in the following areas:
a. Oral communication **2.10, 1.93**
b. Written communication **2.16, 2.01**
c. Use of the chemical literature **1.81, 1.89**
d. Ethical conduct of research **1.98, 2.11**
e. Laboratory safety **2.73, 2.34**
f. Teaching (e.g., TA training) **2.63, 2.44**
g. Proposal writing **3.14, 2.99**
h. Use of appropriate technology tools (e.g., presentation software, modeling programs) **2.28, 2.16**
18. How would you rate the accessibility of appropriate instrumentation during your graduate experience? **1.85, 1.62**
19. How would you characterize the level of financial support (TA or RA stipend, fellowship, etc.) that you received as a graduate student? **2.15, 1.96**
Questions 20 through 28 ask for a response from 1 (strongly agree) to 5 (strongly disagree) or "not applicable (N/A)."
20. Students in my graduate program participated in institutional governance (committee membership, etc.). **3.34, 3.43**
21. Laboratory research in my graduate program was consistently carried out in a safe manner. **2.47, 2.15**
22. I was encouraged to attend and participate in professional meetings. **2.15, 2.06**
23. In graduate school, I developed a network of friends and associates that has benefited me significantly in my professional career. **2.54, 2.29**
24. My graduate department had an effective graduate student organization. **3.20, 3.15**
25. The importance of teamwork was emphasized in my graduate program. **3.01, 2.81**
26. I was satisfied with my overall graduate experience. **2.05, 2.01**
27. I am using the skills and knowledge gained in my graduate program in my current job. **1.87, 1.65**
28. If I had it to do over, I would pursue an advanced degree in chemistry. **2.19, 1.73**

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