cpt Special Report
Committee on Professional Training

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SURVEY OF Ph.D. RECIPIENTS IN CHEMISTRY

PART 2. ANALYSIS OF WRITTEN COMMENTS

The more things change…

"*The length of time required for the Ph.D. should certainly not be less than three years.*"
Comment of department chairman, 1947

"*The exploitation of graduate students in the U.S. is a disgrace. As a reward, after working for five or six years to earn the Ph.D., they are told they are not qualified for work unless they do a postdoc. If after all this work, Ph.D. chemists are not employable without a postdoctoral appointment, the system is broken and must be fixed.*"
Comment by unemployed Ph.D., 1998

…the more they stay the same.

"*I would strongly advise that every graduate department give a good course in industrial chemistry, including field trips and some attention to such matters as patents, activities of chemists in industry, etc., and supplement it with talks on technical subjects and by men in industry.*"
Comment by Ph.D. working in industry, 1947

"*My chemistry department prepared graduates for academics more than industry …[the institution of] concrete steps, such as graduate internships, may be a better approach than professors imagining what industry is like from the hallowed halls of academe. My experience as a retail sales clerk was in some ways a better background for what I do now than some of the chemistry courses I took.*"
Comment by Ph.D. working in industry, 1998

The Committee on Professional Training (CPT) of the American Chemical Society has long been concerned with the health of graduate education in chemistry in the United States. Starting in 1947, CPT published a series of reports[1] that provided information about the requirements, structure, size, and capacity of the Ph.D. programs in chemistry as well as the opinions of graduates of those programs. After a hiatus of about two decades, CPT returned to this area of concern in 1996 with a survey of Ph.D.-granting institutions and in 1998 with a survey of recipients of the Ph.D. degree in chemistry.

The quotations above include two taken from the first report (1947) as well as two comments from the most recent survey. The landscape of Ph.D. education has changed dramatically over the last half century. In 1947, 78 departments were found to offer the Ph.D. degree in chemistry, but by 1996 that number had increased to about 190. Judging by the first quotation, there was apparently concern in 1947 that some schools were graduating students with less than three years of postbaccalaureate education. In contrast, departments in the 1996 survey and Ph.D. recipients in the 1998 survey reported that the average time to degree had increased to more than five years, with some students requiring significantly longer periods of study.

However, some themes have remained more or less constant, though the emphasis may have changed. The third quotation indicates that in 1947 it was already recognized that the Ph.D. programs could do a better job of preparing the graduate for a career in industry. As shown by the final quotation, that concern remains to this day and is perhaps even more prevalent than it has been in the past.

Background of the present survey. Those surveyed were 4000 randomly selected ACS members who hold the Ph.D. degree. There were two groups, one composed of individuals who were 33–37 years of age in 1998 and the other comprising those who were 43–47 years. The average year of completion of the Ph.D. was 1991 for the first group and 1981 for the second. A total of 2381 individuals returned the questionnaires with responses to 26 questions concerning their experience in graduate school. A statistical analysis of those responses along with a commentary was the basis of Part 1 of this report.[2]

Written comments were also solicited. Specifically, the questionnaire included the following invitation:

"*Please elaborate on what you perceive to be the strengths and weaknesses of the graduate program from which you*

received your Ph.D. We are very interested in your opinions about how current practices could be improved to provide today's graduate students with a better, more relevant graduate experience."

CPT was gratified to find that 978 (41%) of those responding provided written comments ranging from a sentence or two to extensive multipage essays with detailed proposals for the reform of graduate education. These written comments are the raw material for this second part of the report on the survey of Ph.D. recipients.

Procedures used in the analysis. Initially, 150 questionnaires were selected for study (evenly divided between the two age groups), and the comments were categorized by subject, resulting in approximately 30 different categories. From these categories, the 11 most frequently mentioned were chosen. Each of these categories was mentioned by more than 6% of the initial group of respondents. In this way, the most important categories were identified.

The analysis was then extended to all 978 reports, and the comments in each category were further described by their nature:

"b" (bad)	This particular feature was weak or missing in my graduate program.
"d" (desirable)	A general comment that this feature is a desirable component of a good Ph.D. program.
"g" (good)	I was generally pleased by the way this feature was covered in my graduate program.

Of course, other areas were the subjects of comments, but their frequency was not sufficient to reach our somewhat arbitrary 6% cutoff. Nonetheless, some respondents held strong opinions on these minority subjects, and a few of these views will be included in the text of the report.

Categories of comments. Descriptions of the 11 most frequently mentioned categories are given in Table 1. Designation of the subcategories as "b", "d", and "g" was sometimes difficult to achieve with precision. Nevertheless, it is hoped that these descriptors will give at least a rough idea of the nature of the comments that were received.

Examination of all responses. Figure 1 is a graphical representation of the comments of the 978 respondents who wrote comments. The data are also listed in Table 2. In Figure 1, the bars have been segmented to show the percentage of "g", "d", and "b" comments. The percentages refer to the fraction of the total respondents (2381) that mentioned a particular category of comment. The three categories having to do in some way with preparation for a career in industry represent "hot spots" in the responses. These three (categories 1–3) were mentioned by 4.5% or more of those providing written comments. The almost total absence of comments indicating that this was a good feature ("g") in the graduate experience (0.0%, 0.3%, and 0.0%, respectively) shows strikingly that those making comments almost universally believe that their Ph.D. education did not provide adequate preparation for a career in industry.

"*The single most important thing your committee can do is to help faculties recognize that industrial work, while different from academic work, is equally demanding, creative, rewarding, and is a first-class career choice!*"
Ph.D. chemist in industry

"*My department treated its graduate students quite poorly, in my opinion. Although it is a prestigious . . . university, the training was very much individual sink-or-swim and really did not prepare us very well for life after graduate school. I left not knowing how to write a proposal, never giving a formal presentation, with no sense of the politics and ways of real science.*"
Ph.D. chemist in industry

Another frequently mentioned topic was the research advisor (category 4; 4.5%). This is perhaps not surprising as

Table 1. Categories of Comments that were Most Frequently Mentioned

1. Courses or other preparation concerning business aspects of a career in chemistry
2. Contacts and interaction with industry
3. Greater emphasis on preparation for an industrial career as opposed to an academic career
4. Effective Ph.D. advisor
5. A broad as opposed to specialized education
6. Emphasis on and experience in interdisciplinary research
7. Teamwork
8. Development of oral and written communication skills
9. Career information and guidance
10. Experience and training in writing papers and proposals
11. Emphasis on the fundamentals of chemistry

Subcategories

"b" (bad)	This particular feature was weak or missing in my graduate program.
"d" (desirable)	A general comment that this feature is a desirable component of a good Ph.D. program.
"g" (good)	I was generally pleased by the way this feature was covered in my graduate program.

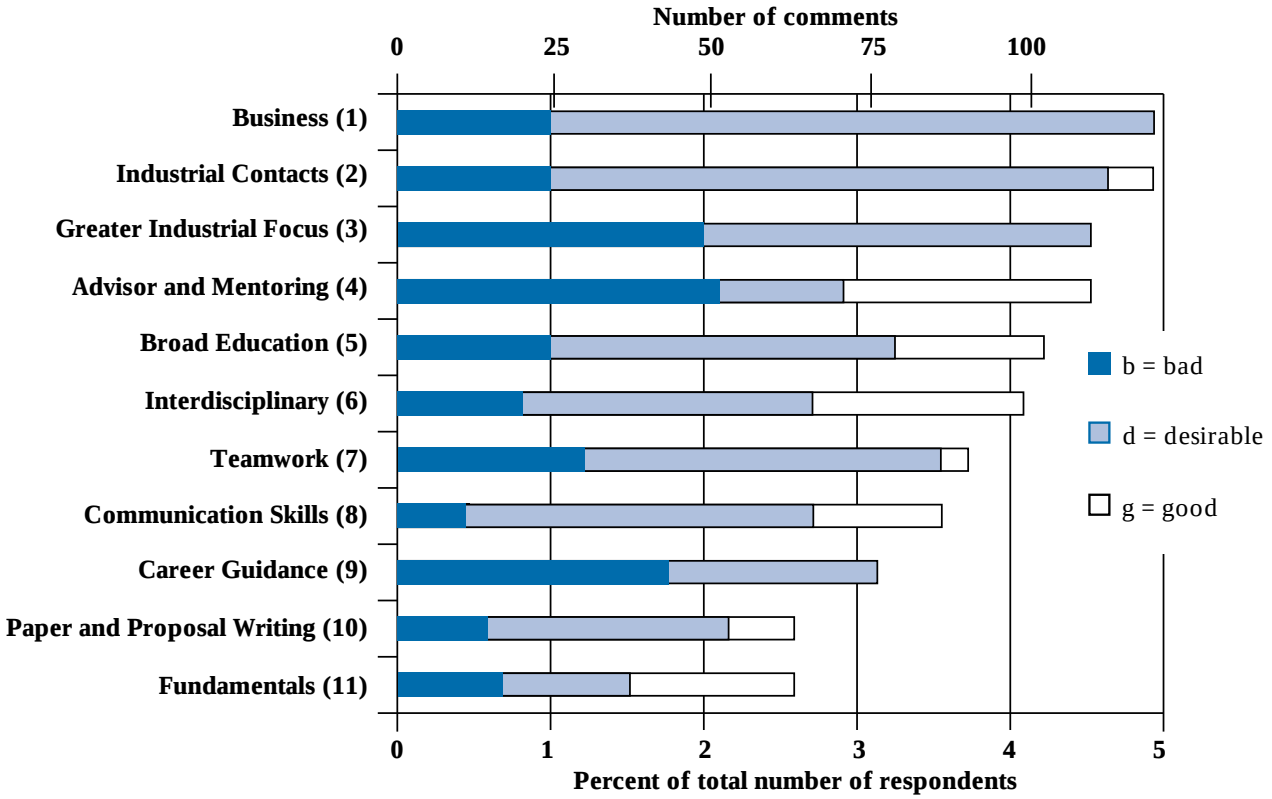

Figure 1. Percent and absolute number of total respondents commenting on topics in various categories, with designation of the nature of the comments as "b", "d", or "g".

the advisor is the person in the program with whom the Ph.D. student works most closely and intensively. Many respondents (1.6%) reported that their experience with the research advisor was good, but an even larger fraction (2.1%) commented that there were problems with this aspect of the Ph.D. program. The remainder (0.8%) simply commented that having a good advisor was important.

Other categories mentioned by around 4% of the respondents were interdisciplinary studies (category 6) and emphasis on breadth rather than specialization (category 5). Of those commenting about the interdisciplinary aspects of the Ph.D. program, one-third reported a good experience in this regard, and only about 20% commented that this feature should not have been a part of their own studies. The largest fraction of those commenting in this area (about half) simply suggested that this aspect should be a part of a good Ph.D. program. Concerning breadth versus specialization, equal fractions (about one-fifth) of those commenting in this area reported this to be a good or bad feature of their own programs, whereas the remaining 60% simply felt that Ph.D. programs tended to be too specialized. It is worth noting that this breadth-versus-specialization question is in a sense the opposite side of the coin compared with category 11 (emphasis on fundamentals), a category mentioned by 2.6% of the respondents. To a certain degree, those advocating less specialization and those wanting to emphasize the fundamental core of the science are two groups pulling in opposite directions. Support for the assertion that there are two groups among those making comments in categories 6 and 11 is found in the fact that of the 152 individuals making comments in these categories, only 9 (6%) made comments in both. The remaining 94% fell into two groups, each of which made comments in only one of the two categories.

> *"In my case, more exposure to industry and industrial chemistry would have been very helpful. . . . The university that I attended resisted collaborative projects with industrial and government labs."*
>
> Ph.D. chemist from "thirties group"

> *"What I found most admirable about my Ph.D. training experience was that my advisor had my education in mind, not his publication list. When he felt that I had learned all that I could from the program, I defended and that was that.... Yet, having recently served on a search committee, I saw students with 10, 15, 20 or more papers from their Ph.D. work. I cannot believe that this is serving the student's interest, only the advisor's."*
>
> Ph.D. chemist from "forties group"

Table 2. Tabulation of Comments According to Category with Industry/Academia Comparison.[a]

Category[b]	Subcategory[b]	All Comments Number (percent)	Comments from Ph.D. Chemists in Industry Compared with those in Academia	
			Industry Number (percent)	Academia Number (percent)
1. Business	d	93 (3.9%)	81 (5.7%)	3 (0.6%)
	g	1 (0.0%)	1 (0.1%)	0 (0.0%)
	b	25 (1.0%)	19 (1.3%)	2 (0.4%)
2. Industrial Contacts	d	86 (3.6%)	70 (5.0%)	7 (1.4%)
	g	8 (0.3%)	6 (0.4%)	2 (0.4%)
	b	25 (1.0%)	23 (1.6%)	1 (0.2%)
3. Greater Industrial Focus	d	59 (2.5%)	51 (3.6%)	5 (1.0%)
	g	1 (0.0%)	1 (0.1%)	0 (0.0%)
	b	47 (2.0%)	40 (2.8%)	4 (0.8%)
4. Advisor and Mentoring	d	19 (0.8%)	12 (0.9%)	5 (1.0%)
	g	39 (1.6%)	27 (1.9%)	8 (1.6%)
	b	50 (2.1%)	23 (1.6%)	17 (3.4%)
5. Broad Education	d	55 (2.3%)	35 (2.5%)	9 (1.8%)
	g	22 (0.9%)	12 (0.9%)	9 (1.8%)
	b	23 (1.0%)	17 (1.2%)	4 (0.8%)
6. Interdisciplinary	d	46 (1.9%)	35 (2.5%)	7 (1.4%)
	g	33 (1.4%)	21 (1.5%)	7 (1.4%)
	b	18 (0.8%)	18 (1.3%)	0 (0.0%)
7. Teamwork	d	55 (2.3%)	47 (3.3%)	4 (0.8%)
	g	5 (0.2%)	5 (0.4%)	0 (0.0%)
	b	28 (1.2%)	25 (1.8%)	3 (0.6%)
8. Communication Skills	d	52 (2.2%)	43 (3.0%)	7 (1.4%)
	g	19 (0.8%)	12 (0.9%)	3 (0.6%)
	b	13 (0.5%)	9 (0.6%)	4 (0.8%)
9. Career Guidance	d	34 (1.4%)	23 (1.6%)	5 (1.0%)
	g	0 (0.0%)	0 (0.0%)	0 (0.0%)
	b	41 (1.7%)	22 (1.6%)	11 (2.2%)
10. Paper and Proposal Writing	d	36 (1.5%)	25 (1.8%)	9 (1.8%)
	g	11 (0.5%)	6 (0.4%)	3 (0.6%)
	b	14 (0.6%)	9 (0.6%)	1 (0.2%)
11. Fundamentals	d	19 (0.8%)	13 (0.9%)	4 (0.8%)
	g	26 (1.1%)	17 (1.2%)	8 (1.6%)
	b	16 (0.7%)	2 (0.1%)	11 (2.2%)

[a] Percentages are computed from the total number of respondents in a given class. For example, to compute the percent commenting in a given area for those in academia, the number of comments made by academics was divided by 5.04 (504 from academia returned the questionnaire; of those, 208 made comments).

[b] See Table 1 for definition of categories.

Three categories mentioned by 3–4% of the respondents were categories 7 (teamwork; 3.7%), 8 (communication skills; 3.5%), and 9 (career information; 3.1%). It may be significant that virtually no respondents reported that teamwork and career information were strong points in their graduate programs. However, in the area of communication skills, more of the respondents reported good preparation (23%) than those who felt that their education was weak in this respect (15%). Finally, a significant number of individuals commented on the desirability of having experience in writing papers and research proposals.

Comparison of comments from different groups: those employed in industry compared with those in academia. The responses of the industrial group (655 of those making comments) and the academic group (208 of those making comments) are presented in Table 2.

> *"Your survey is skewed in the wrong direction. Most of what I know I taught myself. The job of an educator is to get the student to the point at which he/she can pick up on anything related to chemistry."*
>
> Ph.D. chemist in academia

> *"The part of my graduate training in which I feel deficient is in original thought and problem solving. My advisor set out the experiments exactly, and I was not required very often to direct my research, which is the skill I need in my job and have learned on the job."*
>
> Ph.D. chemist in industry

As pointed out earlier, categories involving proper preparation of students for careers in industry (categories 1–3) drew the most comments from the entire group of respondents. As might be expected, these high rates of response are due mainly to those in the industrial group, who were much more likely to mention these categories than their academic counterparts. These trends will be illustrated by discussion of the ratios of frequency of response of the two groups (see box for definitions). The industry-to-academic ratio was 6.4 for category 1 (preparation for business aspects of a career in chemistry), 3.2 for category 2 (industrial contacts), and 3.1 for category 3 (greater emphasis on industrial careers instead of academic). The importance of teamwork was stressed by the industrial cohort (category 7; ratio 3.5), as was the importance of interdisciplinary education (category 6; ratio 1.7). Very few of the comments from either group fell in the "g" subcategory. These results serve to reemphasize the principal conclusion of the statistical analysis in Part 1 of this report, viz., Ph.D. chemists working in industry are much more likely to be dissatisfied with one or more aspects of their Ph.D. education than are those in academia.

> *"My graduate institution did not have a committee to follow the students' progress. Hence, many students are taken advantage of by their mentors."*
>
> Ph.D. chemist in industry

> *"Chemistry departments should not encourage students to major in fields or do research in areas where they know there are limited job opportunities."*
>
> Ph.D. chemist in industry

In two categories the academic cohort was significantly more likely to comment than the industrial group. The ratio of the fraction of academics commenting about emphasis on fundamentals (category 11) to the fraction of industrial people commenting was 2.3, and the academic group was 1.5 times more likely to comment about the research advisor. In this regard, it is perhaps slightly surprising that the academic group was much more likely to report that the advisor was ineffective ("b"; ratio 2.3). In all of the other categories, the frequency and pattern of responses were fairly similar in the two groups.

Ratio = $\frac{\text{frequency of comment by group Y}}{\text{frequency of comment by group Z}}$

Ratios to be discussed: $\frac{\text{Industrial}}{\text{Academic}}$; $\frac{\text{Women}}{\text{Men}}$; $\frac{\text{"Thirties"}}{\text{"Forties"}}$

Comparison of comments from different groups: women and men. Just as was found in the statistical analysis of the responses (Part 1 of this report), there were relatively few differences in the frequency and pattern of the comments received from women and men. The data are presented in Table 3. There also was no significant difference between the gender composition of the Ph.D. chemists who returned the questionnaire (24% women) and those who also wrote comments (26% women). If in each of the categories the total frequency of comment by women is divided by the total frequency of comment by men, one finds that 6 of the 11 categories have ratios falling between 0.8 and 1.2, i.e., the comment rates for the two groups were very similar.

By contrast, women were 50% more likely to write comments about the importance of fundamentals (category 11), 40% more likely to comment about the importance of writing papers and proposals (category 10), and 30% more likely to comment about the importance of communication skills (category 8). However, in each of these categories, the general pattern ("g" : "d" : "b") of comments was very similar for men and women.

Women were 50% more likely to comment about the interdisciplinary aspects of the Ph.D. program (category 6). Those making comments about the importance of fundamentals (category 11) and those emphasizing the importance of interdisciplinary study (category 6) can be regarded as two groups with somewhat opposing views. Support for this assertion can be found in the fact that of the 148 individuals who made comments in categories 6 and 11, only 10 (7%) made comments that fell in both categories. The remaining 93% fell into two groups, each of which made comments in only one of these two categories.

> *"Secondly, the Ph.D. advisor is crucial! The advisor should be a hands-on, active mentor. My advisor was excellent and I learned a great deal from him. This is not always the case with other Ph.D. advisors at many institutions."*
>
> Female Ph.D. in academia

> *"There should be more emphasis on a student developing his/her own interests related to chemistry and less on satisfying the research advisor. Maybe if there were alternative funding sources for stipends, this could be encouraged. I*

Table 3. Tabulation of Comments According to Category with Women/Men and "Thirties"/ "Forties" comparisons.[a]

Category	Subcategory	Comments from Women Compared with those from Men		Comments from the "Thirties Group" Compared with those from the "Forties Group"	
		Women Number (percent)	Men Number (percent)	"Thirties" Number (percent)	"Forties" Number (percent)
1. Business	d	19 (3.4%)	74 (4.2%)	48 (3.9%)	45 (3.9%)
	g	0 (0.0%)	1 (0.1%)	0 (0.0%)	1 (0.1%)
	b	9 (1.6%)	16 (0.9%)	9 (0.7%)	16 (1.4%)
2. Industrial Contacts	d	21 (3.8%)	65 (3.7%)	41 (3.3%)	45 (3.9%)
	g	3 (0.5%)	5 (0.3%)	5 (0.4%)	3 (0.3%)
	b	3 (0.5%)	22 (1.2%)	10 (0.8%)	15 (1.3%)
3. Greater Industrial Focus	d	9 (1.6%)	50 (2.8%)	41 (3.3%)	18 (1.6%)
	g	0 (0.0%)	1 (0.1%)	0 (0.0%)	1 (0.1%)
	b	18 (3.2%)	29 (1.6%)	27 (2.2%)	20 (1.7%)
4. Advisor and Mentoring	d	5 (0.9%)	14 (0.8%)	9 (0.7%)	10 (0.9%)
	g	12 (2.2%)	27 (1.5%)	27 (2.2%)	12 (1.0%)
	b	20 (3.6%)	30 (1.7%)	38 (3.1%)	11 (0.9%)
5. Broad Education	d	15 (2.7%)	40 (2.3%)	31 (2.5%)	24 (2.1%)
	g	6 (1.1%)	16 (0.9%)	9 (0.7%)	13 (1.1%)
	b	4 (0.7%)	19 (1.1%)	15 (1.2%)	8 (0.7%)
6. Interdisciplinary	d	17 (3.1%)	29 (1.6%)	30 (2.4%)	16 (1.4%)
	g	11 (2.0%)	22 (1.2%)	22 (1.8%)	11 (0.9%)
	b	5 (0.9%)	13 (0.7%)	8 (0.6%)	10 (0.0%)
7. Teamwork	d	15 (2.7%)	40 (2.3%)	22 (1.8%)	33 (2.8%)
	g	1 (0.2%)	4 (0.2%)	3 (0.2%)	2 (0.2%)
	b	7 (1.3%)	21 (1.2%)	14 (1.1%)	14 (1.2%)
8. Communication Skills	d	14 (2.5%)	38 (2.2%)	24 (1.9%)	28 (2.4%)
	g	6 (1.1%)	13 (0.7%)	12 (1.0%)	7 (0.6%)
	b	6 (1.1%)	7 (0.4%)	8 (0.6%)	5 (0.4%)
9. Career Guidance	d	10 (1.8%)	24 (1.4%)	22 (1.8%)	12 (1.0%)
	g	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	b	12 (2.2%)	29 (1.6%)	27 (2.2%)	14 (1.2%)
10. Paper and Proposal Writing	d	12 (2.2%)	24 (1.4%)	19 (1.5%)	17 (1.5%)
	g	4 (0.7%)	7 (0.4%)	5 (0.4%)	6 (0.5%)
	b	4 (0.7%)	10 (0.6%)	11 (0.9%)	3 (0.3%)
11. Fundamentals	d	6 (1.1%)	13 (0.7%)	15 (1.2%)	4 (0.3%)
	g	9 (1.6%)	17 (1.0%)	17 (1.4%)	9 (0.8%)
	b	6 (1.1%)	10 (0.6%)	13 (1.0%)	3 (0.3%)

[a]See Table 2 for explanation of percentages.

would have benefited from more direct help with writing proposals and making professional contacts."

Female Ph.D. in academia

The category of research advisor was also more frequently commented upon by women than by men. Strikingly, women were almost twice as likely to make unfavorable comments about their own research advisor than were men (category 4; "b"). This is completely consistent with the results of the statistical analysis reported in Part 1, where the overall evaluation of the effectiveness of the research advisor was significantly lower for female than for male respondents.

Comparison of comments from different groups: "thirties group" and "forties group". As pointed out earlier, the survey was conducted with two groups of identical size, one composed of Ph.D. chemists who were 33–37 years of age in 1998 and the other of those who were 43–47 years. For lack of better terminology, these have been called the "thirties group" and the "forties group". The average date of completion of the Ph.D. was 1991 for the "thirties group" and 1981 for the "forties group". Thus, examination of the responses of the two groups could offer insight into how Ph.D. education and the students' per-

ception of it changed over the period of a decade.

The statistical analysis of the responses of these two groups that was reported in Part 1 did reveal some significant differences, but these were fewer in number and in degree than the differences between academic and industrial chemists. An important difference that was found between the "thirties group" and the "forties group" was that the members of the former were much more likely to report that they would have benefited from more courses in chemistry.

> "*. . . two to eight formal courses were required. I took nine and audited another. I now teach a large variety of undergraduate chemistry courses and am grateful for my broad academic background.*"
>
> Ph.D. chemist from the "thirties group"

> "*We were not required to take any formal classes—it was actually discouraged. This I think is wrong.*"
>
> Ph.D. chemist from the "thirties group"

In considering the comments, once again there were many categories where the frequency of comment was almost identical for the two groups. The data are summarized in Table 3. The ratio of the fraction of the "thirties group" commenting to the fraction of the "forties group" doing so was computed for each category. The ratio fell between 0.8 and 1.2 for 4 of the 11 categories, whereas it was just a little outside this range for category 10 (writing papers and proposals; ratio 1.26) and category 7 (teamwork; ratio 0.74).

The largest difference was found for category 11 (fundamentals; ratio 2.6), where the "thirties group" was much more likely to comment than their older counterparts. A significant number of these comments called for an increase in the number and diversity of chemistry courses that are required in the program. The importance of the advisor (category 4; ratio 2.1) was also stressed more frequently by the "thirties group". Those commenting that their own advisors had been effective ("g"; ratio 2.2) were less numerous than those whose experience was not satisfactory ("b"; ratio 3.2). So, the "thirties group" cited good and bad advisors more frequently than the "forties group", but the latter type of comment was dominant.

> "*As a recruiter for new Ph.D.s entering the pharmaceutical industry, technical competence is certainly very important. However, my personal experience in industry and as a recruiter has shown that teamwork and people skills can make or break a hiring or promotion decision.*"
>
> Ph.D. chemist from "thirties group"

> "*My advisor was a b.....d in some respects, but he taught unambiguously the differences between good and bad data, strong and weak conclusions, and the value of polished presentation skills. These have served me well in my industrial career.*"
>
> Ph.D. chemist from "thirties group"

Career advisement (category 9) drew more comments from the "thirties group" (ratio 1.8). No comments were complimentary ("g") in this area, and the comment rate of the "thirties group" compared with the "forties group" was about equal for comments that career advisement was weak or ineffective ("b") and for comments that this aspect is a desirable part of a good Ph.D. program ("d"). Members of the "thirties group" were also more likely to comment that the Ph.D. program should emphasize industrial aspects as opposed to preparation for academic careers (category 3; ratio 1.6). The difference was largely in the area of those who commented that it would be desirable ("d") for programs to move in this direction.

Finally, the "thirties group" was 50% more likely to comment about the desirability of interdisciplinary education and research (category 6). The younger cohort was twice as likely to comment that their program was satisfactory in this area, a finding that may reflect an increase in the number of students participating in interdisciplinary projects.

Examples of suggestions made by respondents. A few examples of specific suggestions will be listed. They are not exact quotations but have been paraphrased extensively. The suggestions are organized according to the 11 categories of comment.

- Encourage or at least allow those students preparing for a career in industry to take courses in such areas as business, project management, finance, accounting, patent law, industrial/process chemistry, experimental design, and chemical engineering.
- Teach some of the topics listed in the first suggestion in the form of ACS-type minicourses.
- Develop industrial internships for graduate students.
- Appoint successful industrial chemists as adjunct professors to give advice to students and lectures on careers in industry.
- Provide two or more distinct tracts for the Ph.D., including at least programs for those interested in industrial careers and those headed for academia.
- Invite more industrial chemists to present seminars.
- Include industrial chemists as active members of Ph.D. advisory committees.
- Encourage faculty to devote a larger fraction of their efforts to teaching their graduate students in both courses and research.
- Be certain that, in both courses and research, a Ph.D. student is not restricted to a single narrow specialization.
- Too much of the student's education is in the hands of the research advisor. Develop mechanisms through which other faculty are actively involved in the process. Strengthening and redefining the function of the advisory committee are a possible route.

- Provide a mechanism that will make clear the relationships of the student's thesis research to other areas of both an applied and fundamental character, i.e., try to provide the "big picture".
- Develop more interdisciplinary research projects with involvement of several faculty, both chemists and others, in guiding the research work of the student.
- Emphasize the importance of teamwork and, if possible, expose the students to the concepts and practice of teamwork, e.g., group activities directed toward solving a common research problem.
- Be certain that each student has several opportunities to make oral presentations during the Ph.D. program. These can include lectures on the current literature, the student's own thesis research, a research proposal, and presentations at scientific meetings.
- Offer a special short course in the art of making effective oral presentations.
- Be certain that each student is trained in technical writing. This might include the composition of an original research proposal, writing of research results for publication, and, of course, the preparation of the Ph.D. dissertation. Active faculty participation is essential.
- Develop mechanisms for providing realistic and up-to-date information about careers for Ph.D. chemists.
- Provide formal and organized assistance to students seeking employment.
- Return to the fundamentals. Challenge the student to become an expert in his or her field.

Obviously, some of the above comments tend to contradict others, but this simply reflects the fact that they originated from individuals with different opinions. Thus, this survey does not provide a blueprint for restructuring Ph.D. education in chemistry. Rather, it gives faculties and other interested parties an overview of the opinions of students who have received Ph.D. degrees from the universities of this country. Perhaps some of these comments and suggestions will provide the spark needed to initiate significant improvements in our graduate programs.

References

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