A Fresh Look at Ph.D. Education

A Workshop Sponsored by the Council of Graduate Schools and the National Science Foundation Division of Graduate Education

Report by Lewis M. Siegel, CGS-NSF Dean in Residence

On March 31, 2008, leaders in U.S. and international graduate education met with representatives of federal agencies in Arlington, VA, at a workshop entitled "*A Fresh Look at Ph.D. Education*" to consider some key issues that could influence the future directions of doctoral education. The workshop, sponsored jointly by the National Science Foundation Division of Graduate Education and the Council of Graduate Schools, and organized by the 2007-08 CGS-NSF Dean in Residence, Lewis M. Siegel, was comprised of two sessions. The first session focused on what is currently known about Ph.D. completion and on efforts by universities and federal agencies to improve the completion rate in the U.S. The second session focused on new approaches to the education of Ph.D. students, and featured presentations by three internationally renowned speakers. All of the presentations were followed by vigorous discussion. The workshop presentations summarized below can be accessed at ***www.cgsnet.org***.

Introductory Remarks

Following welcoming remarks to the 73 workshop participants by *Carol F. Stoel* (Acting Director, Division of Graduate Education, NSF) and *Debra Stewart* (President, Council of Graduate Schools) on behalf of the sponsoring agencies, *Wanda Ward* (Deputy Associate Director, Directorate for Education and Human Resources, NSF) presented a charge to the workshop on behalf of the National Science Foundation. She noted that NSF currently supports about 34,000 graduate students and 6,000 postdocs through its research grant, fellowship, and traineeship programs. Both the American Competitiveness Initiative and the America COMPETES act directed NSF to both increase and diversify the population of highly trained individuals who will participate in the STEM field workforce in the future. This workshop is an important step in increasing the understanding of both federal agencies and graduate deans about the current state of our Ph.D. programs and how they might be improved. She charged the workshop participants to focus on the following questions: What do the Ph.D. completion data indicate? Are we collecting the right data? What are the barriers to completion? What new approaches to Ph.D. education are there? How can the federal government work with other groups to improve our Ph.D. programs in the STEM fields?

Session I: Current Ph.D. Education: Focus on Ph.D. Completion

William Russel (Dean of the Graduate School, Princeton, and Chairman of the Board of Directors, CGS) opened the session with a brief overview of the Ph.D. Completion Project currently under way at CGS. The project is based on the following guiding principles: 1) Students admitted to Ph.D. programs should have every opportunity to complete their degrees. 2) Understanding and improving student degree completion and attrition is key to increasing the effectiveness of doctoral programs. 3) Graduate deans are in the best position to lead conversations about the best practices that will improve student completion rates. The project, funded by Pfizer, Inc., and the Ford Foundation, is being conducted in two phases which span the period 2004 to 2010 for data collection. It involves 29 research partner institutions (who received grants to supply completion and attrition data for a number of specific Ph.D. programs and to make interventions to try to improve completion in each of them) and 25 unfunded project partner institutions that currently participate in various aspects of the project.

Program and Demographic Data from the CGS Ph.D. Completion Project.
Robert Sowell (Vice President, Programs and Operations, CGS)

Dr. Sowell reported that quantitative data on completion and attrition at the individual program level has been submitted by 30 institutions. The data covers five broad fields, 54 disciplines, and 330 programs, and involves 49,000 students. Data is being collected for students entering in each of the years beginning in 1992-93 through 2000-01. These students have been divided for purposes of analysis into three 3-year cohorts: Cohort A, students matriculating in 1992-93, 1993-94, and 1994-95; Cohort B, matriculating in 1995-96, 1996-97, and 1997-98; and Cohort C, matriculating in 1998-99, 1999-2000, and 2000-01. Data on completion has been submitted by 24 institutions, at the broad field level only, with respect to gender, citizenship, and ethnicity for U.S. students. The demographic database includes 40,000 students. He then described the profile of data for the analysis of 10 year completion rates for Cohort A of the CGS study. Program data for this cohort covers 12,000 students, while demographic data is available for about 9500 students. The distribution across fields is: Math and Physical Sciences, 31%; Social Sciences, 21%; Engineering, 19%; Humanities, 17%; and Life Sciences, 12%.

While the overall 10 year completion rate was 57% for Cohort A, completion varied by broad field: 63-64% in Engineering and Life Sciences, 55-56% in Mathematics/Physical Sciences and Social Sciences, 49% in Humanities. There was a wide range of completion rates within the broad fields---e.g., 44% in Political Science vs. 65% in Psychology within Social Sciences, and 56% in Electrical Engineering vs. 78% in Civil Engineering. Time courses for completion plateau significantly by year 10 in the STEM fields, but not in the Humanities and Social Sciences.

Males complete at significantly (7-9%) higher rates by Year 10 in the STEM fields, while females complete at higher rates (4-5%) in the Social Sciences and Humanities. Annual completion rates tend to be higher for males in early years after matriculation. For example, in Mathematics/Physical Sciences, annual completion rates for women catch up to those for men only in year 6 and are similar after that. In Social Sciences, women catch up in year 5 and their annual completion rates surpass those for men after that.

International students complete at higher rates by year 10 than U.S. domestic students in all broad fields. The differences are greatest in the STEM fields, particularly in Math/Physical Sciences (68% vs. 51%) and Engineering (70% vs. 58%). International students in STEM fields complete with shorter time to degree than domestic students.

Student numbers in some of the broad fields are relatively small for under-represented minorities, so data for individual U.S. ethnic groups should be interpreted with some caution. African American students complete at much lower rates than U.S. whites in Mathematics/Physical Sciences (37% vs. 52%), Engineering (47% vs. 61%), and Social Sciences (47% vs. 57%), but the 10 year completion rates are approximately equal for the two groups in the Life Sciences (60%) and Humanities (51-52%). The time course of completion suggests that African-Americans have a longer time to degree than U.S. whites in the Life Sciences.

Asian Americans complete at significantly lower rates by year 10 than international students in all fields, and at lower rates than U.S. whites in all fields except Mathematics/Physical Sciences where both complete at about the same rate. Hispanic students complete at significantly lower rates than whites in Life Sciences, Engineering, and Humanities, but at approximately equal rates in Mathematics/Physical Sciences and Social Sciences.

The overall rate of attrition for all Ph.D. programs by year 10 is 31%. Attrition rates after 10 years are highest in Mathematics/Physical Sciences (37%) and Humanities (32%), and lowest at about 26-27% in the Life Sciences, Engineering, and Social Sciences. The time courses of both completion and attrition for all students in the STEM fields flatten out before year 10, and a relatively small proportion (9-11%) of the entering cohort remains after year 10. In the Humanities and Social Sciences, in contrast, both completion and attrition continue to rise through year 10, and a much larger fraction of entering students (17-20%) are still pursuing the Ph.D. after year 10. It is interesting that the time course of completion for African American students is qualitatively similar to that for all students in all broad field except the Life Sciences, where completion is continuing to rise through year 10, suggesting that although completion rates are identical for African Americans and whites at 10 years, the time to degree is longer for African Americans in the Life Sciences.

Although there are many analyses which can and been done with current data from the CGS Ph.D. Completion Project (e.g., the effect of institution type---public vs. private; cohort size; year of matriculation; early vs. late attrition), it should be noted that the project is primarily about examining interventions that might improve completion rates and reduce attrition. The participating institutions are conducting exit surveys of completing and non-completing students to gain insight as to factors that influence the decision from the students' perspective. The interventions being studied in the project fall into a wide range of categories, including selection/matching, mentoring and advising, financial support and structure, program environments, research experiences, and curricular and administrative processes and procedures. From the project data, it is hoped that we can determine the relative impact of the various types of intervention, and how efficacy might vary across broad fields and populations.

Discussion:

Q: Does CGS have data on gender within citizenship and/or ethnic groups? Is the number of women in the sample for Engineering sufficient to makes claims about completion rate differences? Are the results for under-represented minorities in individual broad fields statistically significant?

A: CGS has not collected data by gender for citizenship or ethnic groups. This clearly would be important in sorting out, say, the relative effects of gender vs. citizenship in some STEM fields, where a large majority of international students are probably male. About 15% of Cohort A in Engineering were female (277 individuals). While we have done no rigorous statistical analyses so far, the 7 Year completion data for individual ethnic groups with low numbers of students in Cohort A seem to be similar to results for Cohort B, so we believe the results to have some validity.

Q: Does CGS have any evidence that the amount and/or structure of financial support affects completion rates?

A: Such data may indeed come from future analyses of interventions in various programs participating in the Ph.D. completion project. Data from Duke that will be presented subsequently by Dr. Siegel indicates that the amount and structure of funding can indeed have a significant impact on completion rates.

Q: Aggregation of completion rates by broad field masks significant differences by gender within those fields. What would happen to the higher completion rates for women than men in the Social Sciences if Psychology were pulled out?

A: Since Psychology, with the highest completion rates in the Social Sciences, tends to have a higher ratio of females to males than, say, Economics, which has a significantly lower completion rate, the results might well be different for the rest of the Social Sciences. Unfortunately, CGS did not collect data by gender, citizenship, or ethnicity at the program level.

Q: Will the presentations be available of the Web? When do you expect the CGS Ph.D. Completion project demographic data to be published?

A: The presentations will be available on the CGS web site www.cgsnet.org. We expect to publish the baseline demographic data in late Spring 2008.

Q: How does length of study impact completion rates and career choices for students? When is time to degree too long? Does full time vs. part time status affect completion?

A: We hope to get information about these types of issues from the exit surveys administered to completing and non-completing students as part of the Ph.D. Completion Project.

Debra Stewart noted that the data collected so far in the CGS Ph.D. Completion Project has been designed to establish a baseline for conversations on how to improve completion and Ph.D. education in general in the future. Lewis Siegel added that the baseline data, incomplete as it is, has the potential to significantly affect policy decisions at both the local and national levels. For example, does the relatively high completion rate for African Americans in the Life Sciences but not in other STEM fields reflect the requirement, already present for Cohort A matriculants, to show serious efforts to recruit under-represented minorities when applying for and reporting on NIH training grants in order to receive funding?

Data on Ph.D. Completion from Federal Agency Fellowship and Training Programs

The NSF Graduate Research Fellowship Program
William Hahn (Director, Graduate Research Fellowship Program, NSF)

The Graduate Research Fellowship program (GRF) is the oldest NSF program, having been initiated in 1952. More than 43,000 students have received these awards through FY2008. For the period 1978-1998, there were also 2,000 recipients of NSF Minority Graduate Fellowships, but these fellowships have been incorporated into the GRF program for the past decade. The GRF provides 3 years (over a 5 year period) of funding (stipend and cost of education allowance) and travel and cyber infrastructure support, entails no service requirement, and is both portable and flexible in its use. The monetary value of the fellowship has varied over the years, and applicant numbers have reflected these variations. Funding rates have ranged from 8 to 23% of applicants.

For the review and award process, reviewers rank applicants by assigning each a score based on perceived merit. The ranked applications are divided into four Quality Groups (QG's). Those ranked in QG1 receive the GRF award. For those in QG2, program officers have some flexibility if there are factors to be considered such as under-representation of women or minorities in a field or the need to achieve some equity in geographic distribution of awards; but ranking is the key factor in determining the great majority of awards. QG2 contains both funded and unfunded students.

Although there are a number of caveats for evaluation of outcomes data on GRF awardees over time due to differences in contractors and database packages used, as well as the complications introduced by the merging of the Minority Graduate Fellowship program with GRF in 1998, as well as variations over time in eligibility criteria, panelist demographics, and review criteria, there have been a number of studies of Ph.D. completion for GRF fellows – these have ranged from 68% to 80%, with the most recent cohort examined (1994-98) at 78%. In a study of completion rates in STEM fields at UC Berkeley, GRF fellows completed at higher rates than non-GRF fellows (76% vs. 64% in 1987-92, and 69% vs. 64.5% in 1993-98). For all cohorts examined, ranging from 1979 to 1998, GRF completion rates were higher for males than females, 81% vs. 74% in the 1994-98 cohort. Given the 10-year completion rates in the STEM fields reported by CGS, ranging from 55% to 64%, it does appear that the GRF is associated with significantly increased rates of completion.

The NIH National Research Service Awards Program
Walter Schaffer (Office of the Director, Extramural Research, NIH)

The Ruth L. Kirschstein National Research Service Awards program (NSRA) dates back to 1974, and includes traineeships and fellowships for both pre-doctoral students and postdocs. For FY 2007, 84% of the 9,429 NRSA pre-doctoral awards were in the form of training grants and 16% in the form of fellowships. In a study conducted by Dr. Georgine Pion of NRSA awardees for the period 1981-92, it was found that 91% completed within 10 years of their appointment. The overall 10-year completion rate for Life Sciences in CGS Cohort A is 63%. The NRSA award is thus associated with significantly higher completion than is seen with the total student population in Life Sciences.

NRSA trainees and fellows completed the Ph.D. in less time than non-trainees from NIH training institutions (6.5 vs. 6.9 years). A higher percentage of trainees than non-trainees pursued postdoctoral training (78% vs. 60%), were working in research careers (87% vs. 77%), held tenure-line positions (39% vs. 29%), were employed at top-ranked academic institutions (37% vs. 23%), were successful in applications for NIH/NSF grants (67% vs. 55%). NRSA trainees/fellows published more articles after receiving the Ph.D. and had higher citation rates per article than did non-trainees.

Discussion:

Q: Do either of the programs described provide support for professional development of Ph.D. students?

A: NRSA funding from NIH requires training in research ethics, but it does not specify the content of that training.

Q: Are NSF GRF awards given to masters students?

A: About 5-10% of the awardees are master's students.

Q: Have the completion rates been compared for funded vs. unfunded students in GRF QG2?

A: Earlier studies showed higher completion rates for funded vs. unfunded students.

Q: What is the typical pattern of funding for students supported by NRSA training grant awards?

A: While there is no universal pattern for support, the most typical pattern provides service-free funding for the first two years in order to provide time for students to complete courses, do laboratory rotations, and select a mentor for the dissertation project. Students typically are supported on research grants from the third year until completion of the Ph.D. degree.

Q: At what stage do students apply for and receive NSF GRF awards?

A: About one-third of applicants are either undergraduate seniors, first year Ph.D. students, or second year Ph.D. students.

Q: Do any GRF awardees use their awards to study outside the U.S.?

A: About 70 of 3,300 awardees are studying abroad.

Yehuda Elkana stated that there seems to be an assumption that the more students complete their Ph.D. programs the better, but is this necessarily true? What is the quality of students who drop out? Dr. Hahn replied that he believes that attrition in the early years of a Ph.D. program is not necessarily bad, but dropping out after 3 or more years is a problem. Lewis Siegel added that graduate deans are generally interested in minimizing non-academic impediments to degree completion, such as finances and mis-matches between students and their programs based on poor information. Some attrition is always to be expected.

Q: How does funding of students for graduate education in the U.K. differ from the U.S. model?

Mary Ritter replied that funding for Ph.D. students in the U.K. comes from funding agencies, and all students are funded for 3 or 4 years post-masters. Funding comes from the Research Councils, not from grants for specific research projects, and so is directed to education outcomes as opposed to just research.

Q: Given the high numbers of postdocs in certain STEM fields, is there a market for current levels of Ph.D. production in those fields? Is there not a disconnect between the need to have graduate students work on funded research projects and the market for those students when they complete their degrees?

Lewis Siegel replied that many believe this to indeed be the case. He favors a shift of student support from research grants to training grants such as the NRSA or NSF IGERT programs or individual fellowships, so that the focus can be on educating students for the workforce that we need, rather than on a system of inexpensive labor to carry out funded research projects.

Q: If institutions revitalized master's degrees in STEM fields, would this help to solve the problem?

Carol Lynch stated that the growth of Professional Science Masters degree programs is part of the solution.

University Interventions to Improve Ph.D. Completion

Duke University

Lewis Siegel (Vice Provost, Duke University and CGS-NSF Dean in Residence)

The Graduate School of Duke University has performed a study on Ph.D. completion and attrition at Duke before and after a serious of interventions. A faculty consensus on Duke Graduate School goals and policies was reached in the early 1990's: 1) Duke departments and programs should admit Ph.D. students based on their potential for highest quality scholarship rather than primarily to meet service needs of departments or faculty, and 2) Duke should provide adequate funding and minimize service requirements so that Ph.D. students can have time to be students and complete the degree in a reasonable period of time.

Studies at Duke conducted between 1991 and 1995 showed that there were several issues that needed to be addressed in order to achieve these goals: 1) In interviewing students at Duke, it became clear that many students did not know what they were getting into when they applied to graduate school. There was insufficient understanding of the independence required in graduate vs. undergraduate education. There was shock in discovering the reality of the academic job market. There was little realization by applicants of the actual chances of completion and the length of time to degree. 2) Faculty relied heavily on using quantitative measures to screen applicants. High GRE and undergraduate grade point averages defined cut-off score below which applications were not read carefully or at all. An analysis of Ph.D. completion rates at Duke showed that in all broad fields, there was little correlation between GRE scores or UGPA and completion, but, faculty, when presented with sets of applications in either a high GRE/UGPA range or in a much lower GRE/UGPA range could pick out students who had significantly higher completion rates than the Duke average simply by carefully reading the application. It was also found that, in spite of the practice of bring applicants to campus, usually after admission, there was too often a poor fit between actual student and faculty interests. 3) The system of funding allocations to departments to support Ph.D. students had been designed to achieve maximum service at minimum cost.

In an effort to improve completion rates, the Graduate School instituted a number of interventions between the years 1995 and 1998. In order to achieve better informed selection of students, departments were strongly urged to reduce the emphasis on Graduate Record Examination scores and undergraduate grade-point averages, and to carefully read the entire application for all applicants, with an emphasis on demonstrated research experience. In an effort to achieve transparency so that all applicants would know what they were getting into if admitted to graduate school at Duke, data for each Ph.D. program on placement of graduates, time to degree, and completion rates was placed on the Web. Departments began to interview students brought to campus before admitting them, seeking an honest exchange of information between faculty and students, rather than just selling the program.

There were significant changes in the way students were funded in departments in Arts and Sciences. A 5-6 year funding guarantee at competitive stipend levels was offered to all admitted students. Departments were given (3 year) budgets based on graduate education quality parameters (such as completion rate, ability to attract students with competitive merit fellowships, size of faculty actually supervising dissertations, etc.) rather than service needs. Student teaching loads were substantially reduced, and more fellowship and Research Assistant years added. Funding these changes required a significant downsizing of the Ph.D. population in many programs, particularly in the Humanities and Social Sciences. Science departments were urged to give students choice of mentors in years 1 and 2, and not bring in students tied to a specific research grant. The sciences were required to substantially increase external support of their Ph.D. students if they were to avoid downsizing of their graduate programs.

There were a number of programmatic changes as well which were designed to improve the experience of Ph.D. students at Duke. Among these were introduction of field-specific symposia to introduce a variety of career options to Ph.D. students; enhanced students services including a strong investment in subsidizing child care for the neediest graduate students; significant improvements in the training to teach program; and introduction of awards for excellence in faculty mentoring that were highly publicized.

In order to assess the effect of these interventions, Ph.D. completion and attrition rates were analyzed for cohorts of Duke Ph.D. students matriculating in 1992-93, 1993-94, and 1994-95 (Cohort A) and in 1998-99, 1999-2000, and 2000-2001 (Cohort C), and the Duke data compared to national averages for each broad field as determined by the CGS Ph.D. Completion project.

Data for Cohort A, which matriculated prior to the interventions, showed that 10-year Ph.D. completion
Rates at Duke were already greater than the national average in all broad fields except Engineering. In all fields, the attrition rates after 10 years were also equal to or higher than the national average. Thus, in all fields, there were very few students continuing at Duke after year 10 as compared to national averages. This was particularly striking in the Humanities (5% of Duke matriculants continuing vs. 20% nationally) and Social Sciences (2% vs. 17%). The 10-year completion rates for Cohort A at Duke exceeded the national average in all fields irrespective of ethnicity, gender, or citizenship status, with the exception of female and international students in Engineering.

When the completion and attrition patterns at 7 years for Duke Cohort A vs. Cohort C were compared, there was a significant increase in completion in the latter cohort for the Humanities (35% to 46%) and Social Sciences (51% to 63%) as well as a decrease in attrition (Humanities from 29% to 23%, Social Sciences 34% to 27%). These are the fields where the changes in funding and teaching loads would be expected to have the greatest impact. The improvements were widespread: Of the 15 Humanities and Social Science programs, ten had at least a 10% improvement in completion, and ten had at least a 10% decrease in attrition). Completion did not change significantly in four of the programs, and only one showed a significant decrease. Time courses of completion and attrition showed that completion was markedly increased in the years 5 through 7 in Cohort C vs. A and the completion rate for those years was double the national average in Duke Cohort C in both the Humanities and Social Sciences. Attrition increased in the peak years 2 and 3 in Duke Cohort C, but rapidly decreased in later years to below both the Duke and CGS cohorts A.

There was no significant change in 7-year completion rates in the broad fields of Life Sciences, Mathematics/Physical Sciences, and Engineering between Duke Cohorts A and C. Attrition did decrease by more than 10%, however, in the latter two fields. It is instructive, however, to compare programs which participated significantly in the interventions cited above, particularly in terms of student selection, reduction in teaching, and giving students choices in years 1 and 2. Arts and Sciences Biology was one of these, and completion rates and attrition rates improved quite significantly, as did those in Chemistry and Mathematics. There was little change in Physics and Biomedical Sciences, both of which already had funding and teaching/choice practices similar to those described above in Cohort A. Duke departments which did not embrace the changes in selection, funding, and student choice had either no change or decreased completion in Cohort C vs. A.

The rising tide was found to lift virtually all boats. Completion rates increased at Duke in Cohort C vs. A for all U.S. ethnic groups, males and females, and international and domestic students in the Humanities and Social Sciences. In the STEM fields, the results were mixed. Previously low completion rates, as compared to the national average, for females and international students in Duke Cohort A did increase significantly in Cohort C, but the effects on most other groups were modest. Perhaps, most notable was the fact that completion rates for females increased by at least 10% in all of the broad fields except Mathematics/Physical Sciences (where the completion rate, already much higher than the national average in Cohort A, did not change significantly in Cohort C). It seems plausible that the Duke investment in childcare for needy Ph.D. students may have contributed significantly to the increase in female completion.

Dr. Siegel summarized the Duke findings as follows: National data on Ph.D. completion and attrition Provide important benchmarks for individual programs. Improvements in selection, funding, and freedom of choice for Ph.D. students and introduction of targeted support systems, such as childcare, are correlated with significantly improved Ph.D. completion and attrition rates. However, he added, many things were changed in a relatively short period of time at Duke, and so we really have no way to decide which of the changes really had significant affect on improving completion. It is the goal of the CGS Ph.D. Completion Project to come up with some answers to this question.

University of California at Los Angeles
Claudia Mitchell-Kernan (Vice Chancellor for Graduate Education, UCLA)

The Graduate Division has conducted a detailed study of cumulative attrition and completion rates for 13,000 Ph.D. students matriculating at UCLA beginning in 1990 through 2004. The overall attrition rate for matriculating Ph.D. students at UCLA was 42% by Year 15. International students had significantly lower overall rates of attrition than white domestic students, who, in turn, had lower attrition than under-represented minority (URM) students. There was no significant difference in attrition for females vs. males. Attrition is highest in year 2 after matriculation. Attrition rates for all groups were similar through Year 5 and diverged thereafter.

Overall, time courses for completion indicated lower time to degree and potentially higher completion rates for 2000-04 cohorts than for 1995-99 or 1992-94 cohorts. Each successive cohort is doing better than the previous one, with attrition declining in the later cohorts. These latter cohorts received the most benefit from interventions which were introduced at UCLA beginning in 1990. The 7-year completion rate was 38% for the earliest cohort and 47% for the most recent cohort. International students completed at much higher rates than non-URM domestic students, who in turn completed at much higher rates than URM students (67% vs. 56% vs. 45%). Males had slightly higher rates of completion than females.

In the programs at UCLA participating in the CGS Ph.D. Completion Project, Attrition in cohorts followed the pattern 1998-2000 < 1995-97 < 1992-94, while completion in cohorts followed the pattern 1998-2000 > 1995-97 > 1992-94. There were substantial discipline-dependent differences for female vs. male and URM vs. other domestic students.

UCLA has instituted a number of initiatives designed to increase completion and decrease time to degree. One of the most important was the development of a strong institutional database, which has permitted the tracking of longitudinal data of a variety of performance indicators including completion and time to degree. These statistics are regularly shared with the faculty. We now know that the front end selection criteria used to measure the ability of students to succeed in doctoral studies, undergraduate grades and standardized tests are not particularly helpful. There was a substantial increase in fellowship support in the early 1990's. There have also been a number of student support interventions as part of the CGS Ph.D. Completion Project, including interviews with students about attrition, introduction of funding awards based on quality of education, and the Chancellor's Prize awards, but it may be too early to reach conclusions about the specific effects of individual interventions on Ph.D. completion and attrition.

Discussion:

Q: The improvements in completion at both Duke and UCLA are impressive, but have you taken into account the impact that the state of the economy has on Ph.D. enrollments and completion rates?

A: Clearly, there can be higher rates of attrition from Ph.D. programs in specific disciplines when the market for people with bachelors or masters degrees is particularly good, such as in Computer Science and Electrical and Computer Engineering during the "tech-bubble" of the mid-1990's. This no doubt is part of the reason that these disciplines have the lowest completion rates for students in Mathematics/Physical Sciences and Engineering broad fields in the CGS Cohort A data. At Duke, however, we found no significant difference in Ph.D. completion in either of these two disciplines when comparing Cohort A with Cohort C, in which students matriculated after the bubble had burst.

Q: The completion results for the different cohorts in individual programs at UCLA are all over the place in spite of substantial increases in university funding for students and decreased enrollments. What can you say about this?

A: The stories are different in individual departments, but most programs improved and the overall average improved. Although fellowship funding was doubled at UCLA, this accounts for only about 20% of all student support.

Session II: New Approaches to Ph.D. Education

Embracing Contradiction in the Education of New Ph.D.s
Yehuda Elkana (President and Rector, Central European University, Budapest)

Dr. Elkana, a distinguished scholar in the history and philosophy of science, asserted that current Ph.D. education in science is based on one particular strand of the Enlightenment---it presupposes universal and absolute truth, context independence, and abhorrence of contradiction. Yet the design and interpretation of experiments and the theories developed from them always involve assumed tacit and local knowledge and context dependence, and all scientific theories have some degree of inconsistencies and contradictions. It is from these that the next theories generally emerge, and so doctoral education in science needs to emphasize the fundamental assumptions on which current thought in the discipline is based, and the contradictions inherent in the theoretical framework of the discipline at any point in time. There should be regular seminars that emphasize examples of instances in which favored theories do not fully explain the facts. Students must be trained in how to self-reflect on the epistemological fundamentals of the discipline. The Ph.D. program as a whole should focus much more on the state of the field and its uncertainties, with the choice of problem a central objective.

The most important process in the training of a Ph.D. in science should be in finding, choosing, and defining a problem and in understanding how the problem contributes to significant advancement of knowledge. The problem should be viewed from many perspectives and discussed by many people, including faculty and other students. This is something that should not be done alone or simply assigned by a faculty advisor. How does the problem relate to neighboring disciplines? What is the place of the problem in the grander spectrum? The problem should be re-examined at regular intervals. Students sometimes become so focused on their dissertation research that they forget what is going on around them

Doctoral programs should include an understanding of the public context of the student's work and the field in general. In most current programs, the right of a Ph.D. candidate to judge the importance of his work in advancing the well-being of society has been undermined. Also, almost all advanced research is by definition interdisciplinary, but most doctoral education is still based on disciplines. Doctoral programs should pay less attention to work within the boundaries of the various sub-fields of the discipline, and emphasize to a much greater extent the less specialized contexts at which the various disciplines meet. Doctoral education should equip students to work and teach in a variety of settings and to communicate their findings and ideas to non-specialist as well as specialist audiences. Although Americans believe in universal education, U.S. doctoral education strives for the highest quality in producing research scientists and is designed to attract the best students. In that sense, it is elitist. High level scholars indeed benefit from high level students. Yet true research accounts for only a minor portion of the work that Ph.D.s do both within and outside academia. Graduate education needs to develop different types of training for different situations.

Professor Elkana believes that doctoral education is better in the U.S. than in Europe. While the U.S. natural sciences model has spread, in the Humanities and Social Sciences there is often no prospectus, doctoral committee, departmental seminar, or joint discussion of interdisciplinary issues in European universities. Europe is suffering from a "Bologna syndrome", in which doctoral education has been neglected in the focus on creating supposedly employable bachelors and masters degrees. The emphasis has been largely on structure, with little focus on the content of graduate education. However, although the quality of U.S. doctoral education is high, it has not fully lived up to its heritage. While Nobel prize-winners in the past normally worked on problems defined by themselves at the frontiers of their disciplines, often re-thinking the grounds on which questions could be asked, they now too often win the prize for solving problems defined by others. In our curricula, we have too often stopped re-thinking concepts and instead transmit facts. We too often leave little room to argue about un-measurable things, and sometimes these are the most important.

Discussion:

Q: How should educational programs embrace contradiction?

A: It should begin at the undergraduate level with freshman courses in fields such as physics, biology, or economics. They need to learn how theories do not always work in various disciplines or across disciplines. We need to teach contradictions from the beginning, recognizing that all disciplines have paradigms. Students must be given the tools to analyze why we choose one theory over another.

Q: This has huge implications for peer review. How would this be revolutionized?

A: We need to look back for 20 to 30 years for ideas that were rejected for funding by peer review that in fact were important to development of the field. Peer review tends to reward conservative approaches, to reward applications in which the most interesting work has already been done. We need to dare to think differently if we are to bring out the best in the next generation of scientists.

The New Focus on Building Transferable Skills in Ph.D. Education in the United Kingdom
Mary Ritter (Pro-Rector of Postgraduate and International Affairs, Imperial College, London)

In the current global economy, knowledge forms the basis for competitiveness at institutional, national, and global levels as well as for personal development and success. Universities, as the chief developers of knowledge and research potential, are responsible for linking education and research to societal needs, including their application in industry, commerce, and enhancing the quality of life. The link between knowledge development and its application and transfer is mediated by transferable skills.

In a major report by Sir Gareth Roberts on the supply of science and engineering skills in the UK, it was concluded that the training of Ph.D.s in transferable skills needed to be strengthened considerably. "Roberts" funding was provided to permit at least two weeks of dedicated training per year in transferable skills at U.K. Ph.D. granting universities. The major areas targeted for transferable skills training were: research skills and techniques, research environment (ethical issues including peer view, pressure for results, conflicts of interest, secrecy, obligation to the public, and commercialization), research management (including prioritization, time management, realism, project management, data management and IT skills), personal effectiveness (including self-discipline, motivation, initiative, awareness of limitations and training needs), communication skills (writing, oral presentation, professional audiences, public understanding, teaching, and media), networking and team-working (within research group, university, and wider communities, understand behavior and impact on others), and career management (ownership, realistic goals, identifying development needs, insight into transferable nature of research skills, range of career opportunities within and outside academia, effective presentation in CVs, applications, and interviews). Additional key skills include how to operate in an intercultural, global context, skills to operate in an entrepreneurial commercial/industrial context, and outreach, the next generation, and sustainability.

At Imperial College, London, the two Graduate Schools (Life Sciences/Medicine and Engineering/Physical Sciences) are responsible for organizing training of Ph.D. students and postdocs in transferable skills. There is a central specialist academic and support staff as well as a cohort of academic staff from the various faculties and postdocs trained as tutors for the residential courses. Such training is provided through lectures, half to full day workshops, and residential off-campus three-day workshops for all students in their first and final years. There are more than forty courses/workshops available to students including: research integrity, communication and presentation skills, time management and personal effectiveness, stress management, science and the media, commercialization of research, negotiation skills, teamwork, writing skills, teaching assistant training, thesis writing and completing the Ph.D., and planning your career. In addition, there is more specialized training within departments and schools in skills in specialist oral presentations, preparing and presenting posters, preparing manuscripts for publication, writing grants, and assessing manuscripts, publication and grants. Interdisciplinary and intercultural experiences (involving non-U.K. universities) are also important to skills training.

The Roberts report also recommended that universities take responsibility for ensuring that all of their postdoctoral researchers have a clear career development plan. Imperial College offers a program of about eighty different 1-2 day workshops for postdocs in the areas of research management, business skills, teaching and learning, personal transferable skills, and career guidance. In addition, there is a residential two-day course
focused on careers, library Web-CT course, a program of teacher training, and a tutoring program, as well as awards for mentoring and incubator ideas.

There is a structure (UK GRAD) for national coordination of programs for transferable skills training of Ph.D.s which supports delivery of these programs in individual institutions and sharing of information and best practices. There is general agreement that training in transferable skills needs to include multiple modes of delivery: ranging from skills acquisition embedded in specialist academic training to residential "total immersion" residential workshops. It must involve Ph.D.s, postdocs, academic staff, and employers in developing the repertoire of skills training. It needs to cater to a wide range of careers, not just academia and industry. It must find ways to ensure that Ph.D.s and postdocs know and understand what specialist and transferable skills they have, and how to transfer that information to employers. But when all is said and done, it must be remembered that the Ph.D. is still fundamentally about training in research!

Discussion:

Q: The 1995 COSEPUP report from the National Academies recommended similar training in what you are calling transferable skills. Yet U.S. universities are far behind the U.K. in implementing such programs. How can this be changed?

A: The U.K. has created funding sources for training in transferable skills through the Research Councils There is a structure for cooperation and sharing of ideas between programs at individual institutions of higher education. And the training is required for all doctoral students. U.S. funding agencies could set up similar structures and funding mechanisms through, for example, training grants such as the NSF IGERT program.

Q: How specific are the training requirements for Ph.D. students?

A: All first and final year Ph.D. students must participate in the skills training program. They have options as to which workshops to attend. These workshops are offered regularly throughout the year.

Ph.D. Education from the Perspective of Students and Postdocs

Crispin Taylor (Executive Director, American Society of Plant Biologists)

Dr. Taylor began with some practical questions: How do we prepare as many Ph.D. scientists as possible in as many disciplines as possible for rewarding careers in as many areas as feasible? What are the roles of individual faculty members, departments, universities, and funders in this endeavor? How can we ensure that the major demographic shifts that are under way in the U.S. will not render doctoral programs increasingly irrelevant? Or, to put it another way, how can we engage populations that are unfamiliar with doctoral education and thereby ensure that our disciplines remain both healthy and representative? What can we do to modify the existing faculty reward structures and financial incentives that to preserve the current status quo?

Some of the current problems in doctoral education in the U.S. are: Supply without demand. Insufficient numbers of native-born students entering graduate programs. Insufficient ethnic and/or gender diversity. Hurdles to entry. Misaligned objectives. Limited capacity for independent thought. Lengthy and low paying gestation periods for careers. Narrow focus on demanding academic careers. Different definitions of “success”.

Dr. Taylor believes that the objectives of the major participants in U.S. Ph.D. education in STEM fields are poorly aligned. In addition to the interest in uncovering new knowledge, which is shared by all, students want to acquire a tertiary qualification that will lead to higher paying and more influential jobs in the future; faculty principal investigators and universities want to 1) get as much work done as inexpensively as possible, and 2) get funded; funding agencies are charged to support the nation’s scientific infrastructure.

There are both demographic and logistical hurdles to entry. Most URM bachelors degrees are awarded by minority-serving institutions that typically are under-resourced, have few opportunities for undergraduates to perform research, and are poorly connected with major research institutions. Undergraduates in laboratories may encounter super-busy faculty, embittered postdocs, and worried graduate students.

The current system is not conducive to the honing of independent thought---Incoming graduate students are generally handed projects on a plate, resulting in few opportunities to develop one's own research interests and delayed development of critical thinking and project management skills.

The gestation periods for careers are both lengthy and low paying; thus poor short- and medium-term economic incentives risk tipping the balance away from the Ph.D. and toward law, medicine, business, etc. The current situation also results in many Ph.D. students and postdocs feeling that they have been duped. There is a narrow focus in many (but not all) disciplines and universities on emphasizing academic careers, and a pervasive sense that other options are "second best". Students (and faculty) are typically poorly informed about the breadth of post-Ph.D. opportunities.

There are varying definitions of post-Ph.D. success. In academia, the "successful" pattern is typically Ph.D. to postdoc to faculty position at a (preferably major research) university. Outside academia, the "successful" pattern might be Ph.D. (to postdoc) to industry or government. There is a misalignment at many universities between the "successful" pattern and where post Ph.D. students actually go. Dr. Taylor suggests the following definitions of success: For the individual: Acquiring a rewarding position that offers legitimate opportunities for professional advancement. For the institution: Graduating students who are well-prepared for---and well informed about---a broad range of careers. For national funding agencies: Recruiting a diverse population of Ph.D. students that is excited about its post-graduation options.

A number of factors contribute to the current situation: 1) The reward and funding structures in academia strongly favor research excellence and output. This can lead to a "sausage factory" mentality regarding trainees in which the major emphasis is on getting good work done cheaply. 2) The current system is somewhat anachronistic. It evolved in earlier, happier times in which a post-Ph.D. "apprenticeship" was unnecessary and there were plenty of jobs in academia and elsewhere, and has failed to keep pace with the present poor articulation between supply and demand, with the postdoc becoming a holding mechanism. 3) There is great confusion of responsibilities. Faculty are generally familiar with a single professional domain and are ignorant of others. There is minimal engagement at the departmental level, in that there has been resistance to serious tracking of graduates over time. Although there may be some "Career Day" activities, career counseling at most institutions is focused on undergraduates and is poorly equipped to support Ph.D.s. Funders of research projects seem to feel little or no obligation to support professional development of students and postdocs.

Dr. Taylor suggested a number of approaches to help improve the current situation: 1) Recognize that the kindergarten-to-career pipeline is a continuum. Attention must be paid to where students are coming from as well as where they are going. Faculty should see the postdoc as an apprenticeship targeted toward a specific set of future responsibilities, with preparation in such things as project, personnel, and budget management, grant writing, and lab leadership. 2) There should be truth in advertising about Ph.D. outcomes. Departments should know what their graduated Ph.D.s are doing 2, 5, and 10 years post-Ph.D., and whether the faculty is satisfied with those outcomes. Universities need to invest in and fund robust data gathering mechanisms, such as those used by professional and medical schools to track graduates. Graduated students and postdocs should be brought back to network with peers. 3) There should be a serious effort to publicize the breadth of available post-Ph.D. careers. Students should recognize that a Ph.D. in science can open many doors, some more lucrative than others, and that most people with Ph.D.s in science pursue professional opportunities outside academia. This area should provide a potent marketing/recruiting opportunity for attracting Ph.D. students, particularly for populations less familiar with tertiary education.

Doctoral training should focus on developing "T-shaped" people, with both depth of knowledge and ability to advance scholarship, and breath of experience and preparation for a career. In addition to the dissertation, it should provide a range of skill sets and general knowledge. Ph.D. programs should pay pedagogic attention to both strokes of the "T". The Ph.D. should be considered a dynamic qualification which includes attention paid to skills that most jobs demand, such as critical thinking, project management, attention to detail, time management, engaging people, public speaking, writing, and networking. Introduction of professional development into Ph.D. programs should not "just happen". It should involve a deliberate approach by principal investigators on research grants, departments, and institutions to develop transferable skills. Funding agencies should feel obliged to assess funded student and postdoc training in support of diverse career outcomes and require professional development plans in grant applications and reports. They should propagate best practices. And they must work to address supply and demand issues.

In conclusion, Dr. Taylor asserted that, if we want to make changes in doctoral education, we need to 1) ensure that there is some articulation between funding mechanisms and output of Ph.D.s; 2) find ways to reward individual faculty, departments, and universities for preparing well-rounded people who are equipped to apply their skills in a broad range of professional areas; and 3) Seriously involve students and postdocs in the conversation, and place some of the onus on them, too.

Discussion:

Q: The Ph.D. is a research degree. Is there a contradiction in that we are now focused so much in preparing students for non-academic careers that may not involve engagement in research? Also, Ph.D. students in STEM disciplines are funded in large part by tax dollars. What demonstrable value does the nation get from students who do not pursue careers in research?

A: We need to recognize that the Ph.D. must be a dynamic qualification suitable for many alternative career paths. If we do not do this, we will continue to have a declining interest in Ph.D. programs by domestic students, and we will not be able to attract the under-represented minority populations that will be needed for a vibrant STEM workforce in the future.

Q: How do we set priorities with limited resources, for example, between programs for tracking students after Ph.D. completion and programs for recruiting a diverse population of students?

A: We need to do both. Ask for more money.

Q: How can we introduce programs for professional development of Ph.D. students without increasing time to degree? Do we need to eliminate things from the standard curricula for Ph.D. programs?

A: The program for training in transferable skills in the U.K. does not seem to have increased time to degree. We should get the opinions of students and graduates on how valuable some of their courses have been to their overall training for the Ph.D. We know that in many disciplines not much has changed in both curriculum and methods of instruction over large periods of time.

Concluding Remarks

The workshop concluded with brief comments from *Tony F. Chan* (Assistant Director, Directorate for Mathematical and Physical Sciences, NSF) and *Adnan Akay* (Director, Division of Civil, Mechanical and Manufacturing Innovation, NSF).

Dr. Chan stressed the timeliness of the topic of this workshop for NSF and other federal agencies, given the large amount of money that goes to support graduate education and the growing gaps in our STEM workforce. It is time that we did indeed take a fresh look at Ph.D. education, to develop a model that does not follow the current one in which students are often trained to look just like the current faculty. The Carnegie Initiative on the Doctorate was one such effort, focused on individual disciplines, and some of the current speakers have reiterated issues raised in that project. NSF programs such as IGERT and VIGRE (in mathematics) are directed toward broadening Ph.D. education in some of the ways suggested at this workshop. But we need to do much more with universities and funding agencies working in partnership to find ways to improve Ph.D. education in this country.

Dr. Akay found the numbers on Ph.D. completion and attrition astonishing, particularly given the high cost of educating doctoral students. He emphasized the need for both breadth and depth in the training of Ph.D.s, with the goal of training “pi-shaped” people with depth in more than one area and skills to use their training in a variety of settings. He believes that it is now time to seriously discuss new models for Ph.D. education in the United States.