SOME COMPARISONS OF CHEMICAL EDUCATION IN BRITAIN, CANADA AND THE U.S.A.

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In this comparison of chemical education in Britain, Canada and the U.S.A. I have drawn primarily upon personal experiences as an undergraduate, and graduate student at King's College in the University of Durham ('51–'57), and faculty member at the Universities of British Columbia ('58–'66), Princeton ('66–'69) and the University of California at Berkeley (from 1969). There have been changes at my *alma mater* since I graduated and at U.B.C., since I was there, and I hope that my generalized account has taken some heed of them.

The University of British Columbia offered an unusual opportunity for the comparison I am making here, since both the faculty and students (particularly graduate students) were drawn from Britain and the U.S.A. as well as Canada.

Some of the comparisons I shall make do not involve national features. Thus many of the aspects of a chemical education at Princeton arise from the small numbers of students at that University and stand in contrast to features at Berkeley. In many ways the large State and Provincial Institutions of Berkeley and U.B.C. are more akin than are Berkeley and Princeton.

As might be expected, Canadian universities show relationships to both British and United States universities. In training in chemistry, however, the U.S. and Canadian systems have more in common. In some respects the Canadians suffer from burdensome combinations of British and U.S. traditions, particularly in their graduate schools†.

SOME NATIONAL DIFFERENCES

The commendable North American practice of maximizing educational opportunities, generates a very large number of freshmen, many of whom have not made a career choice, even between science and non-science before university entrance. This is in marked contrast to the British student

† It should be noted that Canadian university graduate students not only have to satisfy coursework requirements and examinations comparable to those inflicted upon U.S. students but they are subjected to the same kind of thesis scrutiny and departmental oral examination as administered south of the border. On top of this they are also examined by an external examiner as in the British system. As might be expected, the Ph.D. rejection rate is no higher in Canada!

who has usually, at the age of sixteen, had to choose for or against specialization in science in working for his university entrance examinations. Furthermore, the typical North American freshman chemist has had far less exposure to chemical information than his British counterpart. (It is probable that the Canadian student is a little more deeply prepared than the U.S. student.) Generally then, the North American instructor in chemistry, in contrast with his British colleague, is faced with a large freshman class, of students scantily prepared in chemistry. Certainly this poses one of the more difficult educational tasks in the North American institutions. I shall take up some of the ways in which this problem is tackled later.

Large class sizes are by no means confined only to the freshmen classes in North American universities, but usually by the stage of the specialist courses (third and fourth years) the sizes of classes are roughly comparable with typical classes in Britain. Thus a yearly graduating class of 'honours' chemists of about thirty five members would be a usual number in a British University of 4–5000 students. In North America a class of that size would not be uncommon in a university of 12000 students.

CONCERNING GRADUATE EDUCATION

The commonly held view that the B.S. chemist in North America is less well prepared (at least in coursework) than his British counterpart, may no longer be true. The course work which the former is often required to take to satisfy requirements for the Ph.D. degree is supposed to deal with background deficiencies. Since the typical North American graduate student usually does advanced work at a new institution (indeed many institutions, e.g. Princeton and Berkeley, will allow a graduate to stay on for a higher degree only under exceptional circumstances) he is usually unfamiliar with some speciality of his new school, and is, of course, usually found wanting in it. In Britain it is quite usual for a graduate to stay on for a Ph.D. at the same institution and there is usually little formal coursework required of him. (Incidentally, I have known many chemists both from North American and British institutions who have completed their formal education at one institution. I am not persuaded that it has harmed any of us.)

In my first years at U.B.C. each graduate student was required to take courses and pass examinations in three basic areas (quantum mechanics, advanced organic chemistry and advanced inorganic chemistry.) Depending upon his assessed deficiencies other courses were or were not required. British graduates were quite common at U.B.C. and I was impressed and have remained impressed that even candidates with excellent degrees from major British universities fared no better and occasionally worse in required coursework examinations than their North American counterparts. Of course these same British students, should they have remained in Britain, would have had the opportunity to give their (almost) undivided attention to their chosen research problem. In the U.S.A. it is usual to examine the incoming graduate, and remedial coursework is assigned on the basis of that examination. (Berkeley is unusual in the U.S.A. in that the well prepared student can avoid coursework and immediately proceed to his research.) Princeton, like certain other U.S. universities, also employs a system of cumulative examinations supposedly designed to make the student broaden and deepen his general chemical background. Each student is required to pass a total of six examinations of this kind from a total of eighteen. The examinations are held monthly, each examination being composed of questions submitted by groups of three faculty members selected in random order. For the system to be feasible there has to be considerable choice of questions and the Princeton students have an uncanny knack of predicting which professor's questions (with his known interests) are likely to appear. The system achieves little in my view. The 'cums' are no great impediment to the academically gifted but are a great nuisance to many students and a distinct burden to some, particularly those of lesser academic talent who are devoted to their research work.

A feature of the formal Ph.D. requirements at Princeton (and, I believe, a common feature in U.S. schools of chemistry) is the 'research proposition'. This requires that the student presents (usually in his second or third year) a research proposal in a field *not closely related to his research for the Ph.D. degree.* The candidate is required to defend his proposal in oral examination. There was no such requirement at U.B.C. and British universities do not, as far as I am aware, have such a requirement. Although the requirement can help a departmental Faculty compare imaginative and critical abilities of its graduate student population, it does not, in my view, give the research worth of an individual. Certainly there should be criteria for assessing a student's ability to do creative work (for this is what we are seeking, surely) and the British may well err in having too few checks. I would prefer the graduate student to give an appraisal of his chosen field and defend a proposition in it as a condition for his admission to full candidacy for the Ph.D. Like it or not, we must recognize that excellent research and significant insights usually come only after concentration on a narrow front. Let us not forget that very important attributes for success in research are a certain obstinacy and hard work.

UNDERGRADUATE LABORATORY WORK AND RESEARCH

The bachelor's degree marks the end of training for many chemists in North America as well as Britain. Even some students who have elected an 'Honors' programme terminate at this stage. Usually these people use their special knowledge as the basis for their livelihood (e.g. in high school teaching, chemical sales, etc.). It is clear that we must continue to regard the B.S. degree as terminal and not as a stage in a process normally terminating with the Ph.D. Obviously the chemical training should be broad and as thorough as possible. Probably the most important feature for emphasis (and basic to the continuing vitality of chemistry), is laboratory work.

Practical aspects of chemistry have always been strong in Britain and Europe, and even at the high school level, students have usually had good training in the laboratory. In North America, high school chemistry often does not give the student training in the laboratory and, even in the universities, the large classes often diminish the effectiveness of laboratory instruction. The better North American universities do make great efforts for sound laboratory instruction, but, in spite of this, the practical training of a North American B.S. will not generally have been as broad and well founded as that of his British counterpart.

All university schools of chemistry with which I have been associated have included a research problem in the final year, as a requirement for the B.S. degree. At Princeton there is also the opportunity for juniors to engage in a research problem involving laboratory work. My own experience suggests that the latter arrangement is usually highly beneficial. We all know that coming to grips with a research problem is a richly rewarding experience. The undergraduate usually comes to realize at this time that his 'foundations' of chemical information are not necessarily as firm as he had thought them to be. Furthermore, techniques and theories learned in ideal class exercises are better appreciated for their strengths and weaknesses when applied to 'a real life problem'. It is usually only at the research problem stage that the student has the opportunity to show his creative abilities fully. The success of Princeton juniors in prosecuting research has convinced me that we could well profit from early introduction of 'research' in chemistry training. Of course the small class sizes and favourable faculty/student ratio at Princeton make for unusually good conditions. However, many British schools of chemistry are in an equally good position and could profit from introduction of research problems in the junior B.S. year. It is my view that innovations of this kind would make for an improvement in our ability to select candidates for creative work (for in the end this is the attribute which matters most). We must all recognize that ability to do well in examinations and prescribed laboratory work, are not sufficient criteria for selecting the research man.

FRESHMAN CHEMISTRY

Undoubtedly the greatest differences in university instruction in chemistry, in the three countries I am comparing, occur in the first year. The North American student is not only lacking much of the chemical information familiar to his British counterpart, but is also usually deficient in training in mathematics and physics. It is most unusual for an American freshman to be familiar with calculus and not unusual for him to be unfamiliar with the use of logarithms. The British freshman usually has a much better background in mathematics and physics. Furthermore, the British student is able to devote himself to studies in his chosen subject and their relatives whereas his North American counterpart has usually to satisfy requirements in English composition or literature and a foreign language. On the other hand, the majority of British students enter the university at the age of eighteen, with qualifications which entitle them to enter at the second year level, in the subject which will be their major. Occasionally such a student takes a freshman class, this being a subsidiary subject not covered by the last two years of high school instruction. These features, together with the presence of schools like Nursing and Home Economics on the North American campus, result in much smaller numbers of students in freshman chemistry in British 'Schools' than pertain in the U.S.A. and Canada.

It may seem from this, that the N. American freshman is at a severe disadvantage but oddly enough this does not turn out to be the case. The freshman chemistry instructor in North America† is clearly faced with making rapid progress in a complex and poorly organized subject, usually with very large classes (often of 1 000 students or more). His British counterpart also has his problems, the major one being to overcome the stultifying effect of much learning by rote. He also has the problem of overcoming the boredom of students who are sure they have heard it all before!

North American chemistry faculty recognize that freshman teaching is deserving of much attention. At U.B.C. the large number of freshmen were divided into classes of about 100 students each with a different instructor, who might be an organic chemist, an inorganic chemist or a chemical physicist. Frequent quizzes and the readiness of the class members to interject questions set this experience apart from my own first year experience as a student in Britain. A major problem with the U.B.C. system of many classes, given by different instructors, was the difficulty of setting a fair, uniform and high standard examination. Although the smaller classes were less intimidating for students and teacher alike, I prefer the system adopted by Berkeley. At Berkeley, all of the freshmen take the same lectures from the same instructor (two one hour classes each week). Problems are assigned by the lecturer as homework. This work is handed in to the instructor in the laboratory classes (two three hour periods each week). Care is taken to give the students ample opportunity for help with difficulties. The laboratory classes are small, each class containing approximately twenty five students. Each class has a graduate student teaching assistant who is always on hand to deal with difficulties, supervise laboratory work and check homework assignments. Each class is also under the general supervision of a faculty member (who may be anyone from the Dean of the college or an assistant professor—many of the senior faculty are involved in freshmen teaching). The faculty member spends at least one hour, of his six supervisory hours each week, discussing the lecture material and dealing with problems arising from it. In this way the freshmen students meet the professors—and incidentally come to appreciate that even the professor has his blind spots!

CONCLUSIONS

Since the chemists produced by the British and Canadian and U.S. systems are not markedly different and since we are unable to say that, on the whole, one system is better than another, it is quite possible that some of the 'sacred cows' of each system could be dispensed with without destructive consequences.

Britain could probably benefit from the admission of a greater proportion of its youth to the universities without harming the final standards. On the other hand, North America could benefit from earlier specialization. Creative work has to be fostered and I believe that the earlier the better.

† Perhaps the worst consequence of this instructional task is that 'Principles' of chemistry are given too much stress. Too little emphasis is placed on the approximateness of 'Principles' and instructors appear to be afraid of introducing observations which jibe with the given 'Principles'. Alternative theories are seldom presented. As a consequence of this the student becomes over confident of the power of Theory!

It is necessary to have instruction in depth to foster that commitment and dedication so important to creative work in most spheres, particularly science.

DISCUSSION

J. F. Bunnett (*University of California, Santa Cruz*)—In the U.S.A. it is usual for universities to insist that their graduates should proceed to another university for a higher degree. Is this a sound practice?

N. Bartlett (*University of California, Berkeley*)—I would like to make two comments on why I believe that it is *not* harmful to take both the B.S. and Ph.D. at the *same* institution. (a) Most institutions granting the Ph.D. have a large enough faculty to represent a wide range of fields and interests and the graduate inevitably (as a consequence of biased teaching) has been well oriented towards at least several of these fields. (b) Having spent three or four years in the institution in working for his B.S. degree the prospective graduate student knows the interests, abilities and reputation of his prospective supervisor much better than he can ever know them in the strange environment of a new institution and under the pressure of the need to make a quick decision, in order to embark as early as possible on a Ph.D. programme.

D. Samuel (*Weizmann Institute of Science, Rehovot*)—Would it be desirable to abolish all course work for the graduate student?

N. Bartlett—No, but I believe that every effort should be made to engage the student in research *immediately*. I believe that the student will appreciate coursework much more when he realizes his inadequacies in coping with findings from his research problem. I do believe that thorough courses in quantum mechanics, spectroscopy and computor programming should be offered for students without this background. I see no harm in such courses being taken in the second or third year of the Ph.D. programme.