Review of Chemical Education Research and Development in the U.K., 1972—1976

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In 1972 the Chemical Society established the Education Division on an equal footing with its other specialist divisions. This implied that chemical education was a branch of chemistry in its own right, not engaged in pushing back the frontiers of chemical knowledge, but in extending our knowledge of how to transmit the information gained by the other branches and using chemistry as a vehicle of general education.

At the outset the Education Division found itself in the midst of many educational developments most of which were inspirational and lacking a foundation in research. Many new syllabuses were around with their attendant cohorts of fervent supporters, but little in the way of genuine evaluation was evident. Multitudes of innovations in tertiary teaching were either in being or were on the drawing board giving the impression of a struggle for a place in the sun—a competition for a share of the dwindling number of students interested in reading chemistry. Integrated courses, modular courses, environmental courses sprang up in profusion but, like 'the seed sown on stony ground', they have wilted in the sun and not yielded the expected increase.

At these early stages in the Division's life all one could do was to talk about these things, but little hard evidence was available for a cold evaluation to take place. The Division earned for itself the reputation of a 'talking shop' where nothing was done. Chemists who had looked expectantly to the Division for a lead in educational matters could not be blamed if they drifted away.

However, over the five intervening years the picture has changed. All over the country work has been taking place to give chemical education a more respectable, research-based image. The Division may or may not have played a catalytic role in this, but the changes have been reflected in the nature of its meetings and its publications. In this article an attempt will be made to examine the research and development work in chemical education in Britain in the mid 1970's.

1 General Picture

A. Higher Degrees.—One of the most remarkable expansions has been in the number of centres offering higher degrees in science education. Chairs of Science Education have been established at Cardiff, Chelsea, East Anglia (Chemical Education), Keele, Leeds, and York (Chemical Education), and Science Education teaching and research groups have also appeared at the Universities of Bath, Dundee, Glasgow, Lancaster, Leicester, Reading, and Sussex. The polytechnics have also contributed to the field with particularly active groups at Sheffield and Thames.

These lists are by no means exhaustive because science education is a component of many M.Ed. dissertations from centres all over the country. The combination of a Ph.D. in chemistry with postgraduate teacher training has appeared in the Universities of Leicester and Sussex.

B. Width of Interest.—The theme of the upsurge in interest is summarized in the title of a working paper presented to the Education Division by M. J. Frazer,[1] 'Let's Stop Talking and Find Out'.

The state of the chemical education art is still far from a good basic working theory. It is still at the pragmatic, fact finding stage although there have been attempts to establish the theory before the facts have been adequately researched.[2] In this respect chemical education does not lag behind the rest of educational research because there is still no universally accepted theory of learning nor has human intellectual capacity and growth been satisfactorily described.[3] Indeed some accepted educational research methods may not stand being used by scientists who are critical and numerate and it may be that new research techniques will have to emerge from chemical education research work.

Interest has been concentrated on three main areas: (*a*) the *curriculum*—broadly what is learned and taught and how it is learned and taught; (*b*) *educational technology*—methods, with particular emphasis on individualised learning; and (*c*) assessment of individuals, of curricula and of techniques. Attached to the Division are three subject groups, one in each of these areas.

C. Publication of Findings.—This is the least satisfactory part of the picture.

At present no journal exists devoted solely to the publication of chemical education research. 'Education in Chemistry' publishes research *articles* from time to time, but discourages publication of the detailed statistical information on which the basis and value of research findings can be judged. 'School Science Review', for a period, gave space to a curriculum development section in which research was reported, but this has now been discontinued.[4] The American Chemical Society's 'Journal of Chemical Education' is shy of taking papers about educational research and is very much concerned with the content of chemistry teaching. There are, of course, the psychological journals which from time to time mention chemistry, but they are not normal reading for chemists.

In trying to compile this review the author has been forced to seek information buried in the proceedings of meetings, in private correspondence and working papers, and in higher degree theses or synopses. This is a thoroughly unhealthy

[1] M. J. Frazer, 'Let's Stop Talking and Find Out,' Education and Training Board, Paper 2.76, The Chemical Society, London, 1976.
[2] R. B. Ingle and M. Shayer, *Educ. in Chem.*, 1971, **8**, 182.
[3] J. Nisbet, *Educ. in Chem.*, 1975, **12**, 94.
[4] *School Sci. Rev.*, 1977, **58**, 578.

situation which may well have the effect of quenching further valuable research because workers can find no respectable, well-refereed outlet for their efforts. The quality of the work also stands to suffer since it is not being exposed to the healthy criticism of other research workers except in the narrow confines of a five minute discussion period at some conference.

2 Research on the Curriculum

Although it has been suggested above that the research effort is being directed towards three main areas, these areas overlap considerably and so the reporting of a piece of work under a specific heading will, in many cases, be an arbitrary decision.

A. Objectives.—In common with other areas of education, valiant efforts have been made to follow the 'objectives school' of Mager.[5] As far as secondary courses were concerned it became fashionable to preface new syllabuses by lists of objectives,[6] some of which must have made staunch Magerians blush. There is a distinct impression that the objectives were written after the courses had been constructed. At tertiary level the discussion was condensed in two lectures by Beard[7] and Billing[8] and in an article by Holliday *et al.*[9] in which were set out not only knowledge and practical work objectives but also lists of skills required by a chemist in the use and transmission of his knowledge. Recent pronouncements by 'industry'—if ever industry can speak with one voice—suggest that these skills (communication, decision making *etc.*) are being sought, often in vain, in young graduates entering industry.[10] Whether an education *through* chemistry is being achieved is questioned by Jenkins[11] and others (see ref. 104).

A note of caution about the place and function of objectives in chemical education was sounded by Johnstone.[12] Objectives can be good guides, but can also be chafing halters. There is nothing objective about objectives. There is no sense in which they contain absolute truth. The only research which can be done with them is to see if they are attainable by students at a given stage and then find if students attain them as a result of a teaching situation. An interesting study has been made[13] into the importance which teachers today attach to certain objectives compared with the situation ten years ago. A move away from purely

[5] R. F. Mager, 'Preparing Instructional Objectives,' Fearon, Belmont, U.S.A., 1962.
[6] Curriculum Papers, No. 7, 'Science for General Education,' Scottish Education Department, 1969.
[7] R. M. Beard, in 'Aims, Methods and Assessment in Advanced Science Education,' Heyden, London, 1973, p. 3.
[8] D. E. Billing, in 'Aims, Methods and Assessment in Advanced Science Education,' Heyden, London, 1973, p. 15.
[9] A. K. Holliday, W. J. Hughes, and R. Maskill, *Educ. in Chem.*, 1973, **10**, 215.
[10] C. N. Thompson, *Chem. in Britain*, 1977, **13**, 252.
[11] E. W. Jenkins, *Educ. in Chem.*, 1976, **13**, 84.
[12] A. H. Johnstone, in 'New Movements in the Study and Teaching of Chemistry' ed. D. J. Daniels, Temple Smith, London, 1975, p. 218 (Chapter on Objectives).
[13] J. J. Thomson, 'Practical Work in Sixth form Science,' Oxford University Press, 1975.

knowledge objectives is discernible. A review of practical work objectives has been written by Swain.[14]

B. Concepts.—This word appears frequently in educational literature and it seems that every publication has a different definition. Perhaps the simplest working definition is that given by Lovell[15]—'A concept may be defined as a generalisation about data which are related'. A great deal of work has been done on the growth and attainment of concepts in chemistry, but there seems to be in some of the research the tacit assumption that Piaget's stages observed in the untutored child[16] are equally applicable to a child who is undergoing a programme of structured teaching leading up to the concept.[2] 'Readiness' may be a function both of natural development and the environment (including society, language and schooling). Theoretical work in this area is reported by Shayer and Wharry,[17] by Daniels *et al.*,[18] by Key,[19] and by Tattershall.[20]

A more pragmatic approach in which each concept is broken into component parts and examined in depth using large school populations is reported by several workers. Among these are Duncan *et al.*[21] and Hudson[22] on the mole concept. The concept of chemical equilibrium is examined from both a 'rates' and a 'thermodynamic' point of view by MacDonald *et al.*[23,24] Considerable confusion exists between static and dynamic equilibrium, and a two-compartment view of equilibrium states is evident. A penetrating piece of work by Garforth *et al.*[25,26] demonstrates clearly the place which ionic equations ought to have in school chemistry, and that place is certainly not pre 'O' level or C.S.E. Some of the problems inherent in the learning of organic chemistry are investigated by Kellett[27] and Fensham[28] and substantiated by Furniss and Parsonage.[29] Pupils have great difficulty in identifying functional groups and so cannot categorise compounds and their reactions. A general survey of the school situation[30] shows that there are distinct problem areas which persist into undergraduate

[14] J. R. L. Swain, *Educ. in Chem.*, 1974, 11, 152.
[15] K. Lovell, in 'Growth of Basic Mathematical and Scientific Concepts in Children,' 3rd edn., University of London Press, 1961, p. 12.
[16] B. Inhelder and J. Piaget, 'Growth in Logical Thinking from Childhood to Adolescence', Routledge and Kegan Paul, 1959.
[17] M. Shayer and D. Wharry, *School Sci. Rev.*, 1974, **55**, 447.
[18] D. J. Daniels, D. M. Gower, and G. Lloyd, *School Sci. Rev.*, 1977, **58**, 658.
[19] B. J. Key, M.Sc. Thesis, University of East Anglia, 1973.
[20] H. Tattershall, M.Sc. Dissertation, University of Reading, 1976.
[21] I. M. Duncan and A. H. Johnstone. *Educ. in Chem.*, 1973, **10**, 213.
[22] M. J. Hudson, *Educ. in Chem.*, 1976, **13**, 110.
[23] A. H. Johnstone, J. J. MacDonald, and G. Webb, *Physics Educ.*, 1977, **12**, 248.
[24] A. H. Johnstone, J. J. MacDonald, and G. Webb, *Educ. in Chem.*, 1977, **14**, 169.
[25] F. M. Garforth, A. H. Johnstone, and J. Lazonby, *Educ. in Chem.*, 1976, **13**, 41.
[26] F. M. Garforth, A. H. Johnstone, and J. Lazonby, *Educ. in Chem.*, 1976, **13**, 72.
[27] A. H. Johnstone and N. C. Kellett, *Educ. in Chem.*, 1974, **11**, 111.
[28] P. Fensham and S. C. George, *Educ. in Chem.*, 1973, **10**, 24.
[29] 'Research in Assessment', ed. B. Furniss and J. R. Parsonage, Education Division, Chemical Society, London, 1975.
[30] A. H. Johnstone, *Studies in Science Education*, 1974, **1**, 21.

study[31] and well beyond the age of Piagetian 'readiness', suggesting that too early introduction may cause persistent insecurity in a given concept.

C. Attitudes.—Work in this area falls into two main groups (*a*) attitude developed *towards* chemistry and (*b*) attitude developed *through* chemistry.

Research in the first of these areas is very adequately reviewed by Duckworth and Ormerod[32] and by Gardner.[33] Investigations have been carried out by Palmer[34] into the attitudes of boys and girls to chemistry as a subject and to their chemistry teachers. Marked differences were reported between the attitudes of the two groups. Another survey[35] examined the attitudes of pupils to the historical parts of the Nuffield course and found the girls more favourably disposed than the boys.

The area of 'attitudes through chemistry' has seen a considerable amount of activity. These range from the formation of attitudes sympathetic to the chemical industry to the willingness to apply scientific methods taught in chemistry to everyday problem-solving situations. In the category of development rather than research comes the ambitious venture of the Joint Matriculation Board in launching their Syllabus A.[36] This is clearly biased towards a knowledge of industrial chemistry processes but it goes further in introducing case studies[37,38] linking chemistry, industry, economics, and the environment. Industrial support has been evident in the development of case study packages for schools.[39]

At tertiary level material has been developed[40,41] which encourages interactive group work involving the same factors. Measurements indicate that attitude changes are being achieved.[42]

At middle secondary school level a research programme has been sponsored by the Scottish Education Department to design and test materials intended to promote favourable attitudes towards industry, society, and the environment using chemistry as the medium. Highly interactive techniques are being adopted supported by slides and tapes. Long term attitudinal changes have been reported.[43]

[31] M. J. Galton, J. H. Holloway, J. B. Raynor, and M. J. Tomlinson, *Educ. in Chem.*, 1976, **13**, 38.
[32] D. Duckworth and M. Ormerod, 'Pupils' Attitudes to Science,' National Foundation for Educational Research, 1975.
[33] P. L. Gardner, *Studies in Science Education*, 1975, **2**, 1.
[34] S. Palmer, M.Sc. Thesis, University of East Anglia, 1976.
[35] J. Lazonby, M. A. Stockwell, and D. J. Waddington, unpublished material, University of York.
[36] Joint Matriculation Board, Syllabus A in Chemistry, Manchester.
[37] Chemistry Case Studies, Joint Matriculation Board, Manchester.
[38] G. Hallas and W. J. Hughes, *School Sci. Rev.*, 1974, **56**, 391.
[39] Decisions (1—3), Shell Mex & B.P. Ltd. and Bath University, 1974.
[40] A. H. Johnstone and F. Percival, (*a*) What Happens When the Gas Runs Out? (*b*) Polywater exercise, (*c*) Protein exercise, Education Division, Chemical Society, London, 1977.
[41] K. C. Campbell, M. J. Easton, A. H. Johnstone, and F. Percival, 'The Alkali Industry Exercise,' Department of Chemistry, University of Glasgow, 1976.
[42] F. Percival, Ph.D. Thesis, University of Glasgow, 1976.
[43] N. Reid, Research Report, Scottish Education Department, 1977.

Work on the development of problem-solving techniques for both secondary and tertiary students is taking place.[44]

D. Practical Work.—Concern has been expressed over the effectiveness of practical work at all levels in chemical education. Jones[45] draws attention to its cost and to the functions of practical work as seen by university teachers. Johnstone and McCallum[46] and Gwynne[47] have shown that the intentions of teachers are not being efficiently transmitted to undergraduates through laboratory work. A prestatement of objectives tends to improve student attitudes to the experimental part of the course.[48,49] It is also reported[48] that student attitudes to practical work improve when, from time to time, open ended, 'project type' experiments are introduced into a course to allow students to exercise new skills and encourage inventiveness.[50]

E. Project Work.—This type of practical work now forms a compulsory part of some school syllabuses.[51] The organisation and evaluation of these are reported[30,52,53] showing them to be workable and stimulating. The Chemical Society, Local Authorities, and Chemical Industry have sponsored a number of Project Weeks in various centres for senior pupils and teachers. These have resulted in useful publications.[54]

The most intensive project of all is the B.Sc. by thesis of the University of Sussex in which a research project forms the basis of the practical work for the three years of the degree. A description and evaluation of the course is given by Mathias.[55]

3 Research and Development in Educational Technology

Educational Technology covers a range of teaching activities other than those normally associated with lectures, tutorials, and laboratories, but even these domains have been invaded. All kinds of audio and visual materials, teaching machines, computers, simulations, games, case studies,[56] films, loops, television, and programmed texts appear in this category.

The Educational Techniques Subject Group has produced a catalogue[57] of

44 A. V. Powell, M.Sc. Thesis, University of East Anglia, 1976.
45 K. Jones, M.Ed. Thesis, University of Bath, 1976.
46 A. H. Johnstone and M. McCallum, Proceedings of Education Division, Chemical Society, Nottingham, 1972.
47 E. Gwynne, M.Ed. Thesis, University College, Cardiff, 1976.
48 A. J. B. Wham, Ph.D. Thesis, University of Glasgow, 1977.
49 R. Ritchie, M.Sc. Thesis, University of Glasgow, 1976.
50 D. E. MacDuffie, *Educ. in Chem.*, 1973, **10**, 87.
51 Certificate of Sixth Year Studies, Scottish Certificate of Education Exam Board, Edinburgh.
52 A. H. Johnstone and J. McGuire, *Educ. in Chem.*, 1974, **11**, 50.
53 J. Handy and A. H. Johnstone, *Educ. in Chem.*, 1974, **11**, 56.
54 D. J. Daniels and M. J. Tomlinson, 'Industrial Processes for Sixth Form Chemistry (Book 1),' B.P. Educ. Service, 1975.
55 H. M. Mathias, *Chem. in Britain*, 1976, **12**, 258.
56 N. Reid, *Educ. in Chem.*, 1976, **13**, 82.
57 'Catalogue of Unpublished Learning Aids,' ed. R. B. Moyes, Educational Techniques Subject Group, The Chemical Society, London, 1975.

unpublished learning aids which lists about 150 items from the tertiary sector alone. Various bodies have arranged conferences on educational technology and their published proceedings[58-62] provide valuable lists of available materials.

Advice is offered on the stategy for the production of self instructional materials by Furniss *et al.*[63] With the rise of educational technology have appeared resource centres to house them. In universities and polytechnics throughout the U.K. centres have been set up to enable students to work at their own pace, using a variety of techniques from simple written material to computers. It has been difficult to assess[64] the effectiveness of these centres, but the fact that students use them is probably ample commendation.

The Keller Plan method of individualised instruction has appeared in several centres and assessment of their value appears in a later section of this review.

Computer Assisted Learning in Chemistry (CALCHEM), centred on the University of Leeds with satellite centres across the country, has been described by Ayscough.[65] Many of the programs are used as pre-laboratory exercises in which the student designs his own experiments. Another use of the computer—computer-managed learning—is reported[66] in which the sequence of extended three-hour discussion and library exercises are controlled by the computer and complex calculations are done by it. This allows the students to be involved in discussion and decision-making exercises without the distraction of long, involved calculations. A general review of the state of the computer-assisted learning art is given by Hartley.[67]

For use at secondary and tertiary levels, lists of simulation and gaming material have been published.[68,69] Much of the material is trivial but here and there the techniques have been well adapted to chemistry teaching.

The Chemical Society (Educational Techniques Subject Group) has produced a series of taped lectures by eminent chemists for undergraduate use.[70] These can be usefully employed in resource centres as good background material. The same group is now developing Resource Boxes containing information and teaching aids for school chemistry topics.[71]

[58] 'Independent Learning in Tertiary Science Education,' ed. B. S. Furniss and J. R. Parsonage, Education Division, Chemical Society, London, 1975.
[59] 'Teaching and Learning in Chemistry,' ed. D. S. Trickey, Sheffield Polytechnic, 1972.
[60] 'Alternatives to the Lecture in Chemistry.' ed. L. J. Haynes, P. J. Hills, C. R. Palmer, and D. S. Trickey, Education Division, Chemical Society, London, 1975.
[61] 'Progress in Chemical Education: Teaching and Learning Techniques,' ed. D. S. Trickey, Sheffield Polytechnic, 1975.
[62] 'Educational Techniques in the Teaching of Chemistry and other Sciences,' ed. P. J. Hills, British Association, Surrey, 1975.
[63] B. S. Furniss, C. R. McHugh, and J. R Parsonage, *Aspects Educ. Technol.*, 1976, vol. 10.
[64] A. H. Johnstone, K. M. Letton, and F. Percival, *Chem. in Britain*, 1977, **13**, 423.
[65] P. Ayscough, *Chem. in Britain*, 1976, **12**, 348.
[66] M. J. Easton, A. H. Johnstone, and N. Reid, *Brit. J. Educ. Tech.*, 1978, **9**, 37.
[67] J. R. Hartley, *Studies in Sci. Educ.*, 1976, **3**, 69.
[68] J. Spencer, *School Sci. Rev.*, 1977, **58**, 397.
[69] N. Reid, *Sagset Journal*, 1977, 7, 48.
[70] Chemistry Cassettes, Educational Techniques Subject Group, The Chemical Society, London.
[71] M. Seely, in 'Research for the Classroom and Beyond,' Education Division, Chemical Society, London, 1978, p. 68.

4 Evaluation of Innovations

In the period under review there have been many innovations, but little in the way of hard evaluation of their effectiveness.[72] Sometimes the evaluation has risen no higher than 'pupils seem to like it'. In other cases homespun philosophy places the blame for all the ills of science upon one innovation or another.

A thorough evaluation of the Scottish 'O' Grade, 'H' Grade, and Sixth Year Studies course has been done,[30] showing that all is not well and pointing to possible remedies. The achievements of the affective objectives of Scottish Integrated Science have been carefully studied[73] and this shows that there is no significant difference between junior pupils taught in an integrated course or in separate disciplines as far as these objectives are concerned.

Ingle[2] initiated an evaluation of Nuffield 'O' Level Chemistry which indicated that much of it had been pitched too high. New versions have now been produced.[74] The Science 5—13 Project has also come under scrutiny.[75]

Among the techniques to be evaluated was the modified Keller Plan[76] in Organic Chemistry.[77] For material requiring memorisation and mastery the method was found to be fairly efficient, but very staff intensive and expensive to run. Students showed a preference for a blend of the 'plan' and lectures.

The evaluation of the Sussex B.Sc. by thesis has already been mentioned.[55]

Evaluations have been attempted on the introduction of films[48] and videotapes[78] into undergraduate laboratories to teach basic skills. Illuminative evaluations have been used in both cases and analyses of T.V. recordings have been employed in the former. These visual methods have been shown to be as effective as normal teaching, with the added advantage that students can use them as often as required without tedious repetition by a demonstrator.

Measurements on how well school practical experiments transmit the intentions of teachers have been reported.[79,80] Many teachers expect too much of the experimental work, which is often so detailed as to deny the pupils any room for thought. It has been shown that an experimental course can be devised with objectives of its own and not tied to a theory course. Smaller evaluation studies are reported into certain Nuffield Chemistry Topics[81] and into Case Studies for 'A' Level.[82]

5 Assessment Techniques

This section deals more specifically with the assessment of individual students rather than with the evaluation of courses.

[72] D. A. Tawney, *Studies in Sci. Educ.*, 1976, **3**, 31.
[73] S. Brown, *Studies in Sci. Educ.*, 1977, **4**, 31.
[74] 'Revised Nuffield Chemistry,' Longmans, London, 1975.
[75] W. Harlen, 'Science 5—13: A Formative Evaluation,' Macmillan, London, 1975.
[76] M. H. Freemantle, *Educ. in Chem.*, 1976, **13**, 50.
[77] T. M. Poole, I.U.P.A.C. Symposium, Madrid, 1975.
[78] J. R. Watson, *Educ. in Chem.*, 1977, **14**, 84
[79] A. H. Johnstone and C. A. Wood, *Educ. in Chem.*, 1977, **14**, 11.
[80] D. J. Gunning and A. H. Johnstone, *Educ. in Chem.*, 1976, **13**, 12.
[81] J. H. Barnton, M.Ed. Thesis, University of Bath, 1972.
[82] M. Walker, M.Ed. Thesis, University of Bath, 1972.

The review period has seen a rapid increase in the use of objective testing in both schools and tertiary centres. Most examining boards have an objective element in their chemistry examining. The Chemical Society now holds a bank of objective items[83] which can be purchased for use in tertiary chemistry courses.

Scores on objective items in Nuffield examinations have been used not only to grade pupils, but also to feed back information, to schools and examiners, on general weaknesses.[84] Alternative methods of scoring items to give credit for partial knowledge have been investigated[85] at secondary level. It has been shown that the rank order correlation between objective and written tests increases when credit for partial knowledge is given in both cases. The wisdom of using guessing factors in correcting scores has been called into question[86] and the techniques by which students arrive at the correct response have also been examined.[87] The introduction of film sequences into objective tests to extend their range is described by Oliver and Roberts.[88]

The method of using objective testing at tertiary level has been described, including computer marking techniques and analysis.[89,90] This has been very useful in dealing with large classes and in providing rapid feedback to students.

A series of investigations into objective testing reliability, and the relationship of scores with personality traits is reported.[91,92]

Bloom[93] has for long been one of the high priests of objective testing but even his work has been examined[18,94,95]—in particular the validity of his taxonomy. All of the investigations cast severe doubt upon the hierarchical nature of the taxonomy and one[95] doubted the usefulness of the taxonomy as a tool of communication among educators.

There has been a growing concern about the language of testing, particularly since the number of candidates in external examinations has risen. It was thought that the less articulate pupil would benefit from objective testing in which he did not have to supply a written answer. However, it has been shown[96] that the wording in objective items, to allow them to have a unique answer, becomes so important that their language content becomes very high. The words which cause most trouble are normal English words which have a special meaning in science. The Chemical Society has launched[97] a vocabulary survey in secondary

[83] Item Bank, Education and Training Board, The Chemical Society, London, 1975.
[84] J. R. Leece and J. C. Mathews, *School Sci. Rev.*, 1975, **57**, 148.
[85] S. Friel, M.Sc. Thesis, University of Glasgow, 1976.
[86] J. Handy and A. H. Johnstone, *Educ. in Chem.*, 1973, **10**, 47.
[87] J. Handy and A. H. Johnstone, *Educ. in Chem.*, 1973, **10**, 99.
[88] P. M. Oliver and I. F. Roberts, *Educ. in Chem.*, 1974, **11**, 132.
[89] A. H. Johnstone and D. W. A Sharp, *Chem. in Britain*, 1972, **8**, 66.
[90] R. J. D. Rutherford and D. S. Trickey, *The Technical Journal*, 1973, **4**, 14.
[91] J. M. Freeman, M.Sc. Thesis, University of East Anglia, 1974.
[92] R. M. H. Hind, M.Sc. Thesis, University of East Anglia, 1974.
[93] B. S. Bloom, 'Taxonomy of Educational Objectives (I). Cognitive Domain,' Longmans, London, 1956.
[94] R. Merritt, M.Sc. Thesis, University of East Anglia, 1974.
[95] N. C. J. Chokotho, M.Sc. Thesis, University of East Anglia, 1975.
[96] J. R. T. Cassels and A. H. Johnstone. Scottish Centre for Maths, Science & Tech. Educ. Bulletin 11, 1977, p. 11.
[97] Chemical Society Education Division Newsletter, Autumn 1977.

schools and colleges in an effort to compile vocabulary lists related to age and also to students whose first language is not English. This should be of value to examiners, writers, and teachers.

Traditional examination methods have also been studied, particularly with regard to the treatment of scores[98,99] and choice patterns within papers.[100] The use of standard scores rather than raw scores results in minor changes in order of merit, but might change degree classification.

The external examination of practical work in schools has been questioned from time to time. Two investigations have been reported in which internal assessment moderated by external pencil and paper tests has been attempted;[101,102] only partial success was claimed in both cases.

Moving from the area of purely cognitive measurements, a Test Manual for Science Understanding Measure (SUM) has become available.[103] This 20-item test sets out to measure the understanding of the nature of science and scientific activity.

Another area of testing which will probably develop rapidly is that of attitudes and transfer of scientific skills. Hadden *et al.*[104] report an attempt to compare science specialists with non-science specialists in their willingness and ability to apply scientific techniques to everyday problem-solving situations. No significant difference was reported between the groups. Much of the work done in this area, particularly in the U.S.A., is of dubious value because of the gross misuse of statistical techniques.

6 General Research, Research Methods

Hoare has been examining academic standards[105] and their variation between examination boards and between tertiary institutions. He has detected substantial disparities between centres, showing that candidates with low 'A' Level performance can obtain 'good honours degrees' if they choose the 'correct' college.

A useful collection of papers on educational research methodology has been edited by Parsonage.[106] These include research design, interview techniques, test construction, and application of results to course design.

A timely paper by Frazer[107] brings into question the kind of educational

[98] E. Leblond, R. J. D. Rutherford, and D. S. Trickey, in 'Progress in Chemical Education: Teaching and Learning Techniques', Sheffield Polytechnic, 1975, p. 94.
[99] D. E. Hoare, in 'Research in Assessment,' Education Division, Chemical Society, London, 1975, p. 39.
[100] J. R. Parsonage, 'Research into Tertiary Science Education', Society for Research in Higher Education, 1973.
[101] J. G. Buckley and R. F. Kempa, *School Sci. Rev.*, 1971, **53**, 24.
[102] D. J. Gunning, Ph.D. Thesis, University of Strathclyde, 1977.
[103] P. Coxhead and R. Whitfield, Aston Educational Enquiry Monograph No. 1, 1975.
[104] R. A. Hadden, J. Handy, and A. H. Johnstone, *Educ. in Chem.*, 1974, **11**, 206.
[105] D. E. Hoare, *Chem. in Britain*, 1976, **12**, 151.
[106] J. R. Parsonage, 'Research into Tertiary Science Education,' Thames Polytechnic, London, 1972.
[107] M. J. Frazer, in 'Research for the Classroom and Beyond,' Education Division, Chemical Society, London, 1978, p. 80.

research which has been done for university teaching. His recommendations are:

(i) Universities should encourage their staff to devote at least 5% of their research effort to studying the teaching and learning of their subject.

(ii) Each department should have one or two staff who, in addition to their subject expertise, will have specialised in education. These would be responsible for training and advising their colleagues in educational matters.

(iii) Research on teaching and learning should be made respectable and accorded equal importance to traditional research in consideration for promotion.

(iv) Learned societies should promote journals dealing with research in teaching and learning.

(v) Research should be concerned with immediate classroom problems and should recognise that education is about individuals and not statistical samples.

There is certainly a need for field research, the results of which are applicable to the teaching situation. For the application to take place there must be dissemination processes to communicate findings. Without good journal outlets much of the work is in vain.

Statistical surveys[108] of the British chemical education scene show a bleak picture of falling or static student numbers; of students disenchanted by science in general;[109] and of limited employment prospects for chemists. The 'answers' to these problems are largely inspirational, with little foundation in fact. Clear, unequivocal research divorced from political opinion and expediency is required to clarify the picture and expose the true underlying causes.

[108] Statistics of Chemical Education, Education and Training Board, Chemical Society, London, 1976.

[109] D. Duckworth and N. J. Entwistle, *Studies in Sci. Educ.*, 1977, **4**, 63.