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NYHOLM LECTURE*

New Trends in Chemical Education and Chemistry Teacher Education Worldwide

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1 Introduction

I have waited a long time for this day. In August of 1985, I received a letter from the President of the Royal Society of Chemistry inviting me to deliver the Nyholm lectures and accept the Nyholm Medal during the 1986/87 academic session. This very happy news was followed by a series of spinal operations that made it impossible for me to come to the United Kingdom last spring to lecture and participate in the Ceremonies and International Symposium in London. This disappointment has been replaced by the excitement and anticipation of coming here for this occasion. I am very pleased to be invited and to be able to be with you today.

I met Sir Ronald Nyholm on at least two occasions; no more impressive chemist existed. He was not only a giant in research and a great supporter of chemical education but also a man of personality, style, and good humour. I first met him at an international meeting held at the American Chemical Society in Washington in 1968. Later at a dinner, I sat next to Sir Ronald and watched him match wits with another noted storyteller, Henry Teterin from the USSR. Sir Ronald was delightful. A few years later in an IUPAC Chemical Education Symposium, I had the opportunity to see and hear the depth of this man's commitment to the improvement of chemical education. I am very honoured by receiving this award and by the opportunity to speak today, in remembrance of Sir Ronald Nyholm and his commitment to excellence in chemical education.

2 New Directions/Trends

Some new directions in chemical education are evident in the world today. I am going to note three major changes that are occurring. Throughout this lecture I will, in one way or another, endorse and expand on these three as I highlight the role of the teacher:

Learning to use new technological tools in classroom and laboratory

Dealing with social issues and the higher order thinking required (*e.g.* decision making, problem solving)

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Providing chemical education for all; the need for scientific literacy.

As I develop these themes, I will focus quite specifically on one component of chemical education, *teacher education.* Teachers hold the keys to learning success for the students; teachers are the multiplying factors. Each chemistry teacher in a year influences more than a hundred students, and in a career, thousands of students. The degree of preparedness of the teacher often determines the quality of science education a nation provides. It can be high quality and support a nation's goals or it can be low quality and grievously interfere with manpower development and public understanding. It is the teacher who can motivate some students to seek careers in science and technology and educate all others to the point where they achieve a functional level of scientific literacy.

When we identify the most significant factor promoting excellence in chemical education, it is the teacher that matters. Confidence, commitment, creativity, and compassion are well identified characteristics of a good teacher. While a tendency toward these characteristics may be innate, they are brought to the forefront by experience and education and they are refined over time. The quality of the preservice experience sets the expectations of the teacher and the continuing inservice education of practising chemistry teachers allows good teachers to become even better.

Inservice education programmes for chemistry teachers have been evident in many nations around the world since the early 1960s at least. Perhaps they existed before that time, but were not well known or well documented. With the advent of curriculum reform in the early 1960s, as characterized by ChemStudy in the United States and the Nuffield Chemistry Programme in the United Kingdom, and their diffusion to many areas of the world, the need to prepare practising teachers to use new curricula in their classrooms led to the development of inservice programmes. These have continued to evolve to meet national needs.

3 International Status of Teacher Education

What is happening around the world in chemistry teacher education? I have recently completed a study for UNESCO where I had the opportunity to speak with chemical educators in person at international meetings or to correspond with the leaders in many nations.[1] My findings indicate that teacher education has settled into a relatively routine pattern in most areas of the world. The pattern features inservice workshops and courses designed to upgrade the teacher's knowledge of chemistry and teaching skills. Very few of these programmes are helping teachers to address the three trends noted earlier: high technology, social issues, and scientific literacy.

In a few areas of the world there are definite stirrings and new activities. There is growing recognition of the importance of the teacher's role in nations around the world whether they be developed or developing. Let me cite just a very few examples (Figure 1).

[1] Marjorie Gardner, 'Chemistry Inservice Training', *New Trends in Chemistry, Volume VI*, UNESCO, Paris (in press).

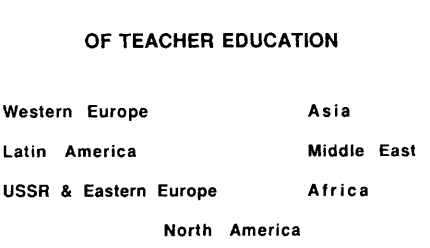


Figure 1

In Latin America, the Tenth International Conference on Chemical Education was held last summer in Sao Paulo, Brazil. More than six hundred participants, mostly from Latin American nations, came together to learn from one another as well as from the excellent panel of speakers. The next step in Latin America is a very ambitious conference to be held in Argentina this summer. It is the First International–Argentinian Meeting on Methodology in the Teaching of Chemistry, scheduled for June 22—25. Invitations have gone out to leading chemical educators throughout Latin America and a number of other countries inviting them to come together to examine how a teacher performs in the classroom and how to improve this performance—the approaches and methods of teaching chemistry.

In Asia, the Chinese government has just published a very detailed teacher's guide and sourcebook for chemistry teachers. It begins with sections on methods of teaching (*e.g.* preparing for and conducting the laboratory, leading discussions). The majority of the book is devoted to chemical reactions, chemical and physical properties of elements and compounds, common uses of chemicals, *etc.* This compendium of chemical knowledge is being distributed to all the provinces to assist the chemistry teachers in that vast nation. In Japan, the inservice teacher education programmes are carried out through the science education centres in each prefecture. This localized system provides opportunity to every chemistry teacher in Japan for regular updating courses on content and techniques, including the use of computers and new audio visuals. One note worthy of mention, the well prepared Japanese chemistry teacher at the school level is paid a salary and accorded status very near to that of the university professor.

In Eastern Europe, the pattern is relatively consistent across the USSR and other European nations. Chemistry teachers are prepared in five year preservice programmes that include at least three years of intensive discipline-specific content learning. In the last two years, supervised student teaching, projects related to teaching, extensive training in methods, use of audio visuals and demonstrations become central in the curriculum. A particularly interesting inservice programme in the USSR comes from the Novosibursk University which sends out its post-graduate students across the vast areas of Siberia that this university serves. The purpose of their travels is to identify talented students for admission to the specialized science boarding school, and also to instruct teachers in the rural areas

in order to enhance their knowledge of chemistry and bring it up to date.

In the Middle East, Israel has been a very active nation for nearly thirty years in providing continuous curriculum and teacher education reform. Other areas of the Middle East follow rather traditional patterns with limited inservice workshops and teacher preparation courses available. In Africa, activity is limited primarily to local teachers in the area of universities. In India, the National Council for Educational Research and Training provides leadership to the various states.

There is no need for me to speak about the United Kingdom and Western Europe. You are the experts and I have come here to learn more from you.

The conclusion in the UNESCO study is that there is not much that is innovative going on in teacher education in large segments of the world. Much more needs to be done.

4 Chemistry Teacher Education in the United States

Now I will turn attention to that which I know best. The need for improved teacher education in the United States and some new programmes that are emerging to help meet that need. The literature abounds with evidence of need and recommendations for change.[2–11] A recent research study indicates that nearly all 77 000 teachers of science at the secondary level in the United States teach at least one course out of their field of preparation.[4] More than half of these teachers have their primary teaching assignments in a field other than the one for which they were initially prepared. Sometimes called 'crossover teachers', these are people who might be fully prepared in biology teaching and credentialed in that field, for

[2] '1986–87 Nationwide Survey of Secondary School Teachers'. A working paper for the Advisory Workshops, American Institute of Physics, February 17, 1987. (A study of physics teachers and students in American secondary schools, 1986–87.)

[3] '1987 Survey of Member Science Centers'. Association of Science and Technology Centers, 1987. (Statistics about teacher education programmes offered at science and technology centres.)

[4] 'Report of the 1985–86 National Survey of Science and Mathematics Education'. Research Triangle Institute, November 1987. (Statistics showing degree of science preparedness among American teachers, K-12.)

[5] 'Science Achievement in Seventeen Countries: A Preliminary Report'. International Association for the Evaluation of Educational Achievement (IEA), 1988. (A comparison of science achievement of American students with science achievement of students in 17 other countries.)

[6] 'Survey Analysis of U.S. Public and Private High Schools: 1985–86', draft copy. National Science Teacher's Association, Washington, D.C. April 1987. (Statistics regarding teacher preparedness in the sciences, and science course availability.)

[7] 'Teacher Supply and Demand in California: Is the Reserve Pool a Realistic Source of Supply', Policy Paper No. PP86-8-4, Policy Analysis for California Education, August 1986. (Statistics to project the need for increased number of teachers in California for the next 5 and 10 year increments.)

[8] 'Opportunities for Strategic Investment in K-12 Science Education; Options for the National Science Foundation', SRI International, May 1987. (Mandated by Congress, this is a study of programmes, options, and recommended initiatives and budgetary levels.)

[9] Marjorie Gardner, Testimony before United States House of Representatives Subcommittee on Science, Research, and Technology, Committee on Science, Space and Technology, Washington, D.C. March 22, 1988, pages 23 to 30.

[10] Carnegie Forum on Education and the Economy. *A Nation Prepared: Teachers for the 21st Century*. Carnegie Forum on Education and the Economy, 1001 Connecticut Avenue, N.W., Washington, D.C. 20005, 1986.

[11] The Holmes Group. *Tomorrow's Teachers: A Report of the Holmes Group*. The Holmes Group, Inc., 501 Erickson Hall, East Lansing, Michigan 48824-1034, 1986.

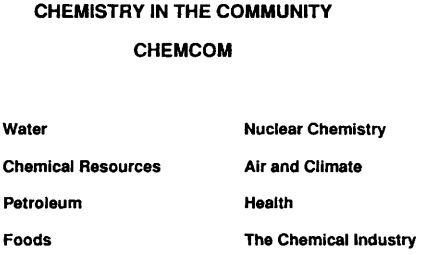


Figure 2

example, but are assigned to teach chemistry with as little preparation as one chemistry course at university level. They are teaching from a weak background and it is difficult for them to be either as knowledgeable or as enthusiastic as necessary.

A series of programmes, largely funded directly by the National Science Foundation or by the Department of Education with funds channelled through the States have been designed. Their purpose is to strengthen the backgrounds of teachers ranging from those with very inadequate preparation to the most excellent and in grade level from kindergarten to twelfth grade. As examples, I will cite four new programmes that are making a difference for chemistry teachers and that have the potential to have much more impact in the next three to five years.

A. Chemistry in the Community, CHEMCOM.—The first is *Chemistry in the Community*, CHEMCOM (Figure 2), a new course for senior high school students developed under the sponsorship of the American Chemical Society and with funding from the National Science Foundation. This course is composed of eight modules that address socially relevant problems that are chemically based. They include food, water, health, nuclear energy, air and climate, petroleum, chemical resources, and the chemical industry. An extensive teacher's guide and two week intensive teacher preparation workshops are the resources being utilized to implement this programme in the classroom. The CHEMCOM course requires extensive laboratory activity; it is socially relevant and it promotes decision making, problem solving, and other higher order thinking skills. Materials to help the teacher implement the programme include not only the teacher's guide, but videotapes and special publications on safety and waste disposal, for example, are a part of the teacher package. This course is being introduced into American schools this September and intensive teacher preparation inservice courses are scheduled across the nation for the next three years. CHEMCOM represents an important new direction—a professional society, ACS, taking responsibility for curriculum development and teacher education. In another innovative move, the ACS is also

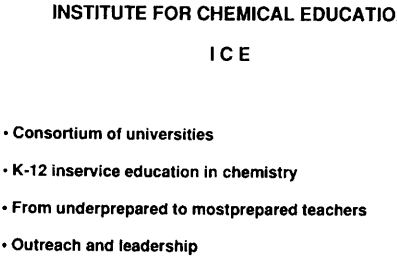


Figure 3

developing an accredited Chemical Education degree programme to be offered in university chemistry departments.

B. The Institute for Chemical Education, ICE.—The second programme is the Institute for Chemical Education, ICE (Figure 3). This relatively new programme comprises a consortium of chemistry departments in major universities and provides an array of chemical education activities designed to reach and serve teachers from kindergarten through twelfth grade level and from the least prepared to the most prepared teachers. The ICE programmes include: (1) updating/fundamentals courses for the underprepared 'crossover' chemistry teacher; (2) supplements courses to prepare teachers to operate chemistry camps for children and to capitalize on demonstrations; (3) instrumentation courses where *Opportunities in Chemistry: Today and Tomorrow* serves as the framework to help the most experienced teachers learn about the theory, research, and practical uses of instruments such as nuclear magnetic resonance, lasers, gas chromatography, research computers, and new electrochemical instrumentation; and (4) special leadership conferences and workshops that allow groups of excellent chemistry teachers to attack specific problems in chemical education.

I will use my own institution to illustrate how the ICE programme works. Through the Lawrence Hall of Science and the Department of Chemistry at Berkeley, forty teachers per summer from across the nation participate in the ICE fundamentals/upgrading course, another twenty in the ICE instrumentation course, and twenty more in the ICE laboratory leadership course. The laboratory leadership group, composed of award-winning teachers, is engaged in a three-year effort directed at finding effective new ways to assess the learning that occurs in the laboratory, identifying the factors that inhibit laboratory activity, and promoting further use of laboratories by incorporating micro-experiments and computer interfacing activities into the curriculum. In all three programmes at Berkeley, teachers are prepared with ideas and materials to take home and share in outreach programmes for large numbers of colleagues in their region. The headquarters

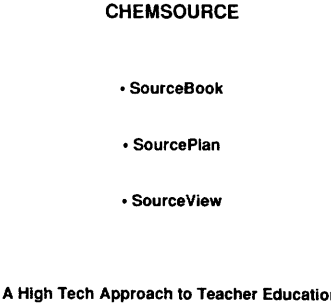


Figure 4

of the ICE network is at the University of Wisconsin at Madison, and other institutions engaged in ICE activity are the University of California, the University of Arizona, the University of Maryland, and the University of Northern Colorado. The networking, outreach, and continuous innovation in teacher education that are possible when such a powerful group joins forces and shares experience and resources, are important characteristics of this new type of teacher education.

C. CHEMSOURCE.—The third example is now on the drawing board, but it has powerful potential for the future. It is a programme called CHEMSOURCE that consists of three components (Figure 4). The first is SourceBook, a very detailed data base that contains essentially all of the help and information a teacher needs, including content and methods specific to particular chemistry topics (*e.g.* acids and bases, equilibrium, stoicheiometry) in either hard copy or disk format. SourceBook is designed to be updated at least biennially, to access other data bases, and to be available and used in every teacher's preparation room. The second component is ChemPlan, a computerized lesson planning toolkit that can draw on SourceBook and the many other new chemical education databases such as the Reactivity Network, the ICE programme, and the CHEMCOM teacher materials. This tool can be used for daily, weekly, and long-term lesson planning in preservice methods courses as well as by individual teachers in their own prep rooms. The third component of CHEMSOURCE is SourceView, a series of videotapes that will capture exemplars of effective handling of difficulties and opportunities in the classroom.

Teams of experienced high school and college chemistry teachers from across the nation are organized into cluster groups to produce this new teacher education resource, CHEMSOURCE. The initial planning has been done; if funded by the National Science Foundation, the work will begin in August of this year. The timetable calls for development, testing, and final production within a three-year period. The power of this innovation lies in giving teachers ready access to a world of assistance through computerization, video, and laser technology.

D. Industrial Initiatives in Science and Mathematics Education, IISME.—The fourth is a very active partnership of industry and education in support of teachers

Figure 5

(Figure 5). Industrial partnerships have existed for decades but many of them address superficial problems and provide the frosting on the cake but are not sufficiently embedded to have significant impact on classroom teaching and on students' attitudes and learning. IISME is a relatively new programme that has been developed in the San Francisco Bay Area under the leadership of about forty major corporations (*e.g.* IBM, Chevron, Hewlett Packard, AT&T, DuPont, Dow Chemical, *etc.*), the school systems of a nine-county region, and the Lawrence Hall of Science, where staff serve as the researchers and educational facilitators of the programme. The programme is already being replicated in other areas of the United States and in Denmark. Such exciting and substantial results from the programme are apparent that major time, effort, and resources are being invested in IISME.

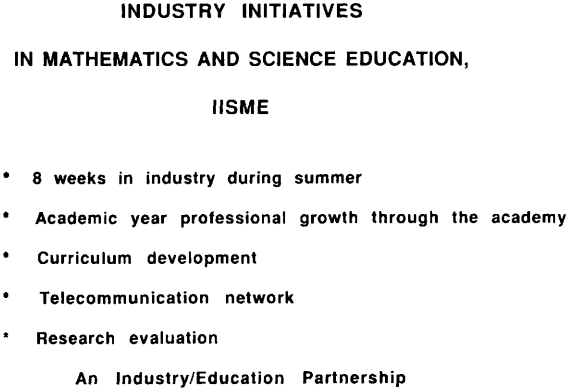


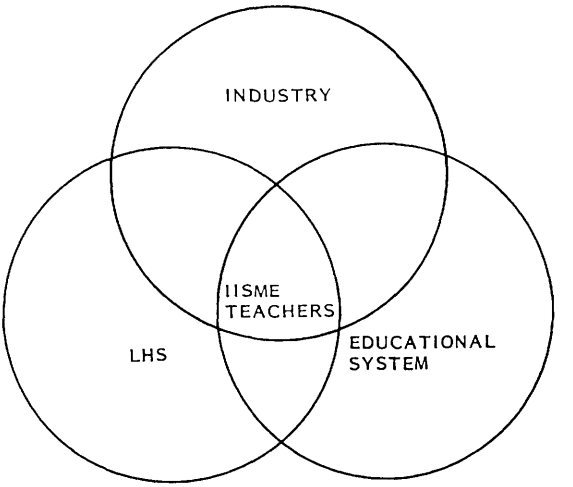
Figure 6

Some of the results from industry's perspective are: (1) teacher performance and productivity exceeded industry's expectations; (2) a functional partnership was established with the schools; and (3) greater respect for and understanding of teachers and teaching. Equally important are the results from education's perspective: (1) teachers' knowledge, especially of real world science and technology, was expanded and updated; (2) recognition of the value of group work, interpersonal communication, and problem solving/critical thinking skills; and (3) more effective teaching and career counselling through enhanced teacher credibility (Figures 6—12).

In IISME, the industries are the initiators, the Lawrence Hall staff are the facilitators, and the teachers are the implementers as they carry new knowledge, skills, and teaching units back to the classroom. The industries and the National

THE IISME PARTNERSHIP

IISME



IISME LINKS SCHOOLS WITH INDUSTRY AND GOVERNMENT RESEARCH LABORATORIES VIA SUMMER INDUSTRY ASSIGNMENTS FOR TEACHERS. THE LAWRENCE HALL OF SCIENCE PROVIDES ONGOING SUPPORT FOR TEACHERS TO INTEGRATE THIS INDUSTRY EXPERIENCE INTO CLASSROOM ACTIVITIES.

Figure 7

PROGRAM MECHANISMS

IISME

- PROVIDE SUMMER INDUSTRY ASSIGNMENTS FOR TEACHERS
  - UPDATE TEACHERS' TECHNICAL AND COMMUNICATION SKILLS
  - DEVELOP APPRECIATION OF TECHNICAL CAREERS AND FAMILIARITY WITH INDUSTRY STANDARDS AND PROCEDURES
  - AUGMENT SALARIES
  - START TO "RECOGNIZE" THE TEACHING PROFESSION
- EXPAND PARTNERSHIP BETWEEN INDUSTRY AND EDUCATION
  - ENCOURAGE INDUSTRY TOURS, GUEST SPEAKERS FROM INDUSTRY TO CLASSROOMS, EQUIPMENT LOAN/DONATION, ONGOING DIALOGUE
- HELP TEACHERS TRANSFER SUMMER EXPERIENCE TO THEIR STUDENTS AND COLLEAGUES

Figure 8

IISME

STATEMENT OF NEED

SHORTAGE OF SCIENTIFIC AND TECHNICAL PERSONNEL THREATENS U.S.

- DEMAND OUTPACES SUPPLY
- STUDENT INTEREST AND ACHIEVEMENT IN MATH AND SCIENCE ARE DECLINING
- PRECOLLEGE MATH AND SCIENCE PROGRAMS ARE INADEQUATE
  - OUT-OF-DATE CURRICULA AND EQUIPMENT
  - 6000 MATH AND SCIENCE TEACHERS LEAVE TEACHING ANNUALLY FOR OTHER EMPLOYMENT
  - OVER HALF THE BAY AREA MATH AND SCIENCE TEACHERS ARE NOT CREDENTIALED IN THOSE SUBJECTS
- FACULTY IS UNDERPAID
  - TWO OUT OF THREE CALIFORNIA HIGH SCHOOL TEACHERS WORK AT A SECOND JOB TO AUGMENT EARNINGS

Figure 9

IISME

INDUSTRY'S PERSPECTIVES

- EXCELLENT MENTOR/MANAGER/EXECUTIVE SUPPORT FOR PROGRAM
  - MEANINGFUL TEACHER ASSIGNMENTS WERE LOCATED
  - PERFORMANCE OF TEACHERS EXCEEDED INDUSTRY'S EXPECTATIONS
  - MINIMAL TIME AND COST TO ADMINISTER PROGRAM
- KEYS TO SUCCESS
  - APPOINT EFFECTIVE COORDINATOR TO WORK WITH IISME
  - IDENTIFY MENTORS WITH TECHNICAL BACKGROUND AND INTEREST IN EDUCATION
  - IDENTIFY JOB DESCRIPTION BEFORE TEACHER IS SELECTED AND PLACED
  - ALLOW TEACHER ACCESS TO COMPANY RESOURCES (PERSONNEL, LIBRARY, TRAINING, ETC.)

Figure 10

Science Foundation are now supporting spin-off academic-year professional growth programmes, telecommunication networks, curriculum development, and research. The importance of IISME is that it is developing an industry/education

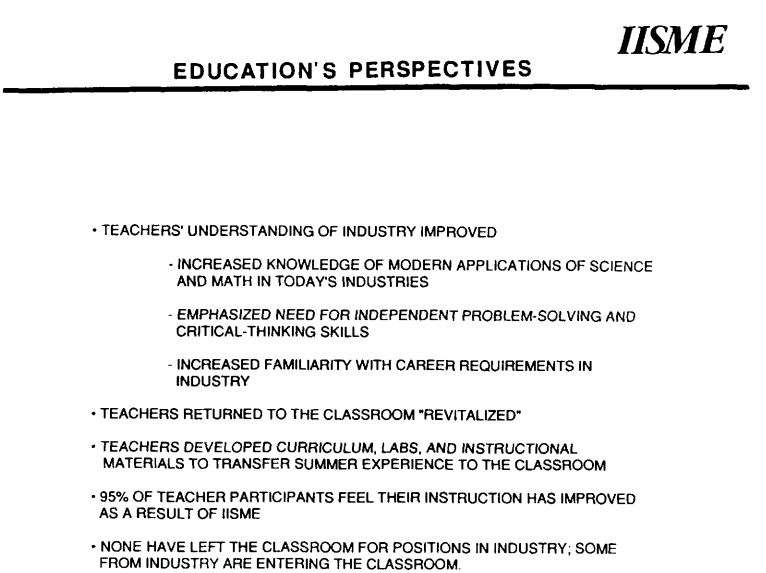


Figure 11

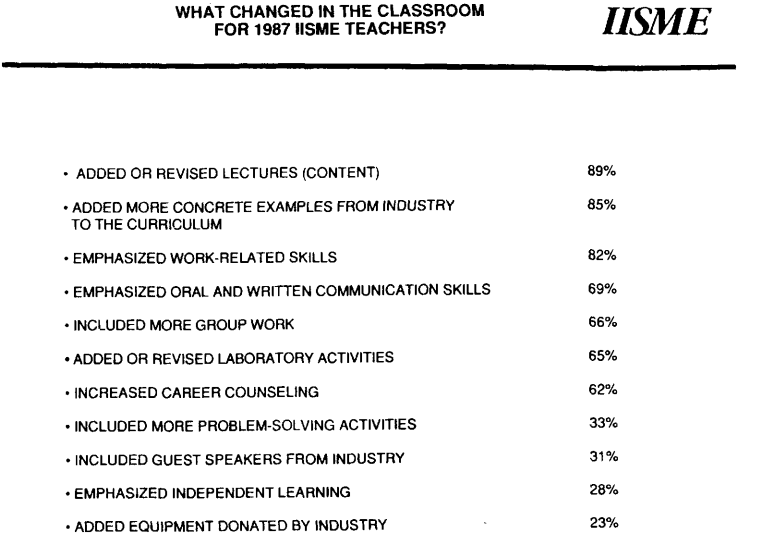


Figure 12

partnership that works; commitments are being forged that are deep and long-lasting.

The four programmes just described—CHEMCOM, ICE, CHEMSOURCE,

and IISME—represent our efforts to address the trends initially noted. These included learning to use technological tools, dealing with social issues, and making chemical education available to everyone.

A new day is dawning in chemical education. The world is reawakening to the value of the teacher, the instructional programmes in the schools, quality in all we do, and the need for change. We must pursue new ways to improve the preparation of our teachers and continuously upgrade their knowledge of chemistry and of research results related to teaching. Recognition of excellent teachers for their achievements and exchanges between and among teachers within each country and across national boundaries are important directions we must pursue.

I would be most happy to discuss any of these ideas in detail with individuals or with groups, in person or by correspondence. At the same time, I plan to learn much more about the preservice and inservice education of chemistry teachers in this nation. I thank you for inviting me and for the honour of giving the Nyholm Lecture.

Related Literature

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