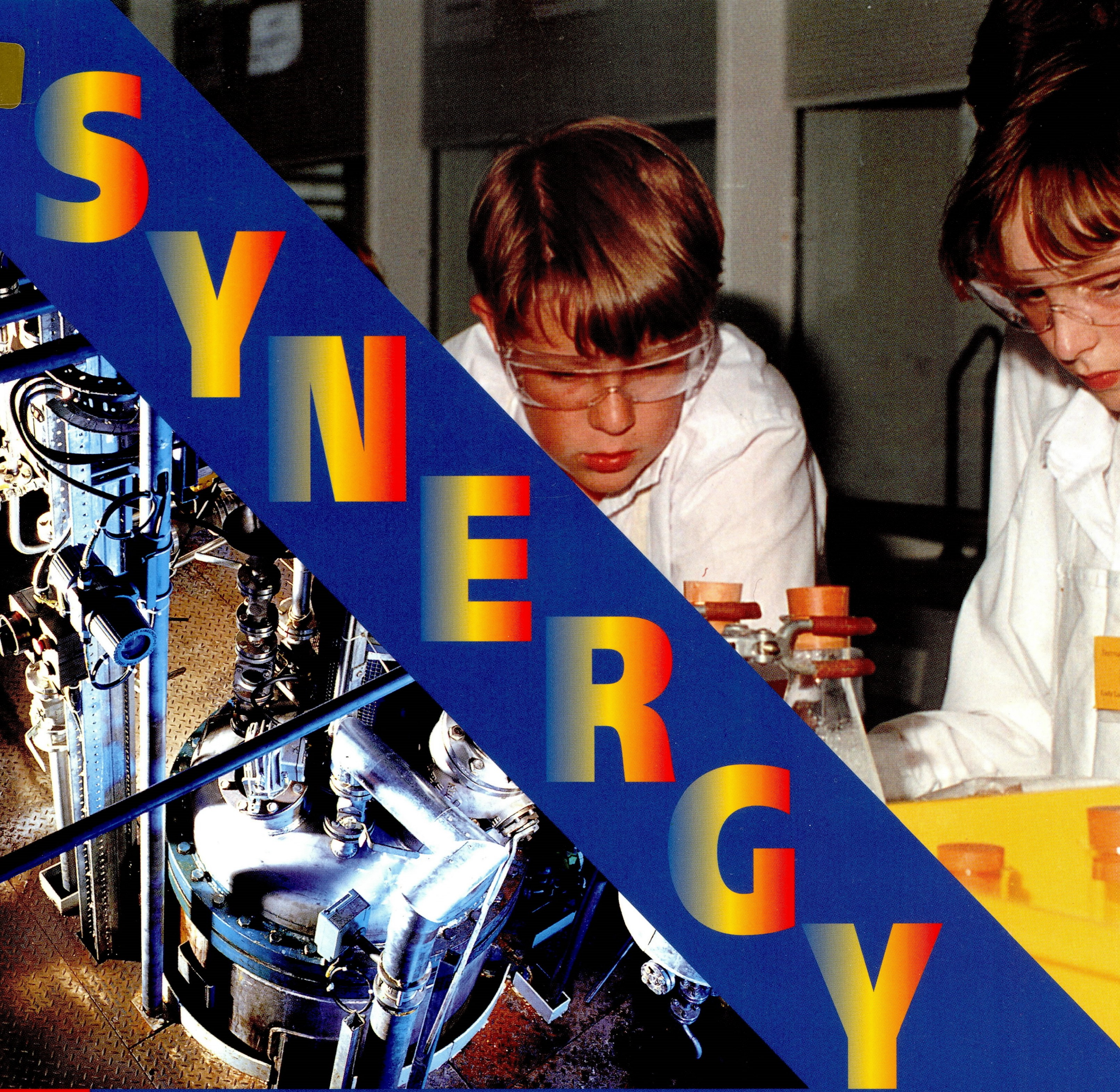
SYNERGY



5 Case Studies on Education-Industry Partnerships

Synergy

5 case studies on industry-education partnerships

NATIONAL

CENTRE

Synergy has been published by the:

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First Published 1996
ISBN 1 85342 566 4

Acknowledgements

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The chapters retain the original American and English spellings as preferred by the authors.

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Preface

Why does the chemical industry try to help in the world of education? As well as the customers to whom we sell quality products in order to make a profit, we have to consider other groups, such as our employees, suppliers, local communities etc. There are several reasons for involvement in education, for example ensuring that:

- there is a stream of qualified people coming into the industry, to enhance research and development, technical service and to be competent to operate increasingly complex plants and processes;
- the public is sufficiently scientifically literate to participate rationally in decisions society makes about science based industries.

Governments such as those in the UK or USA - and possible other developed economies - may not adequately provide resources for the education process. Industry can sometimes help in a small way in areas where it feels it can gain most from enlightened self-interest.

One way in which industry can 'raise the flag' that good science teaching is important is by sponsoring awards to teachers in order to encourage excellence. In addition, many companies have produced educational material for schools which is associated with the individual company and its products.

However, it is initiatives in which industry is partnered with an education establishment that lead to the most successful ventures. The key challenge is to find the best way of ensuring that industry and education work successfully together. Then the science-based industries can contribute to people's understanding of the benefits brought by industry, and help foster the excitment and intrinsic intellectual satisfaction that a better understanding of the natural world can give.

I believe the five initiatives described in this publication each offer an excellent introduction into how such industry-education partnerships can be harnessed to benefit young people.

David Giachardi
Director, Courtaulds plc
London, UK

INTRODUCTION

Following the suggestions of the participants of the workshop "*Developing Teaching Materials in Collaboration with the Industry*", at the 13th International Conference on Chemical Education (ICCE) held in Puerto Rico, August 8-12, 1994, we publish this book which presents details of some successful industry-education initiatives in chemistry being developed worldwide.

The objective of this publication is to describe and provide quick access to information on the history, involvement of teachers, methods of working, teaching resources produced and other achievements of the different groups. The expected result of this book is not a *how to do it* manual for chemical educators but a collection of papers that describe how different groups have encountered and handled major issues and problems while developing their programmes. Accordingly, it is hoped that the material presented in this book will provide new educators with some insights to setting up industry-education projects.

It seems that there is a strong consensus among science educators that science education is in urgent need of reform. Most science teachers agree that the central role of science education must be to give every student the ability to understand important issues - environment, energy and medical advances - in a scientific context. Students should be able to recognise and understand the scientific process and acquire knowledge about facts, concepts, and principles of science to understand public issues. People need to know how the modern technological society works. At the secondary level, science education should be introduced to students remembering that they are science users and not yet science makers.

There is a need to teach more about science in schools and universities. But it would be a serious mistake to design a curriculum solely based on teaching those things about science which everybody knows. The basic facts about science and technology must always be explained clearly by teachers using scientific concepts and principles. The subject presented should be alive and lead to discussions of more controversial issues, where opinions are questionable. But those discussions should have a scientific background and should not be based only on beliefs.

The level of science we should teach will depend on individual needs and desires. What is adequate for a chemist will not be so for a non-specialist. The main task is to give broadness sufficient to satisfy non-scientists and precise and sharp enough to satisfy those who are aiming at science-based careers. Even future chemists will need to know more about other science disciplines.

One of the main reasons for including science education in the secondary level is that our technological civilisation, as we built it (this is also a issue to be thought over), would slowly collapse if people were not spending some time learning science systematically.

The principal defect of conventional science education is that it gives a very one-sided impression of science and technology. A fundamental objective of modern education is to correct this impression by teaching science in its social context. By this means, it is hoped to broaden the background of students of science and to prepare them better for their lives as professional workers and as responsible citizens. The most natural way of approaching science in the light of social issues is through the applications of science.

Many young people do not have a clear idea about their future career but certainly the majority will be non-scientists. Teaching broad aspects of science for those students is no matter for doubt. But how about the minority of students already interested in natural sciences? Will they also enjoy learning science contextualised into social issues? Actually these students can accept a straightforward science teaching, without any extra effort to make the subject interesting. But if these students will be participating in a science community in the future, it is valuable to show them the social involvement of science, because the time where science was done without any engagement with society's needs is gone. Nowadays, to win support for their work, scientists increasingly must be able to show the potentially useful applications of their research aims. More and more research is driven by the commercial needs of companies and the need for rational decision making by society.

We believe that at the secondary school level, science curricula should show not only a scientific image of the world but should also transmit an attitude towards science and scientists. The place of science in the popular culture of our times and the role of the scientists in our contemporary society are largely determined by the way in which scientific knowledge is presented in the classroom. Although most people learn very little science, and make very little direct use of what they learn, they are the silent majority whose views eventually carry much more weight than the minority of specialists.

The Case Studies

The five case studies described here are diverse in their specific objectives but they all have the same general objective, that is, to teach science permeating the political, economic and social issues of our times. Science is taught as it is needed by the student to understand issues of importance to society. These projects are organised in different formats but all of them bring into question the goals of education and science, their roles in our modern society, the relationship between scientific and humanistic values.

Each country has its own pedagogic traditions, and promotes education in its own way. But our science-based civilisation is very similar all over the world. It provides and demands the same range of skilled jobs in about the same proportions. Thus the same scientific and technological knowledge is needed everywhere to carry out these jobs satisfactorily. The fundamental purpose of science education thus imposes a certain degree of uniformity world-wide.

Each chapter of the book conveys lively experiences of groups of chemistry teachers moved by a personal enthusiasm with very little backing from the bulk of the scientific and teaching professionals.

We are educators from various countries, with different experiences but all with an international as well as a national reputation. We each wrote one of the chapters to describe the initiatives in which we are involved. The chapters are briefly summarised below.

Chemical Industry-Education Center
The Weizmann Institute of Science, Rehovot, Israel
Avi Hofstein and Miri Kesner

The authors of this chapter are concerned with science curricula that enable students to apply scientific knowledge to comprehend problems that they encounter within their immediate environment. They started this initiative at the Department of Science Teaching at the Weizmann Institute but today the resources they developed are used to teach the majority of high school students (age 16-18) in Israel. This initiative is based at a Chemical Industry-Education Center. The main activities that help to bring chemical industry into the curriculum are developed: production of special case study teaching materials, in-service training of chemistry teachers and visiting an industrial chemistry plant. Israeli educators from the Center are also concerned with effective development of the students. Several studies were conducted regarding students' and teachers' perceptions.

Israeli authors pointed to a very fundamental issue when looking at curriculum innovation. They mentioned: "We are able to observe that having teachers involved in the planning and implementation of the curriculum decreased their anxiety and reluctance to teach new concepts and subjects and motivated them to use new teaching techniques."

Chemical Industry Education Centre
University of York, York, UK
Miranda Mapletoft

In this chapter, you have a very comprehensive overview of the Centre, clearly describing how it is funded, which is the key to the success of any work. The role of each partner, industry and the Centre, is explained. Reading through the chapter, most of the questions arising in one's mind about an initiative of this kind are answered. The strong liaison between chemical industries, represented by the Chemical Industries Association and the University of York, generate interactive science activities to motivate primary and secondary students to pursue scientific studies and/or careers. The brief description of the materials produced by the Centre illustrates what can be done and how it can be done.

RADMASTE Centre: The Phoenix Programme
University of the Witwatersrand, Johannesburg, South Africa
John Bradley and Keith McCarogher

Ten years ago, a group of South African educators started a project to *develop a more relevant science curriculum* driven by a career need. The subsequent development of resource materials, including the time scale for the process, is described in some detail. Certainly this reading will give, to those educators who are interested, a good perception of the forethought needed prior to undertaking similar initiatives. The authors describe how a project can grow up from a small idea of career recruitment to the internationally known Phoenix Programme.

Science Education Programs: A USA Model of Industry-Academic Partnership in the Dense Urban Area of Orange County, California
Irvine School of Physical Sciences, University of California, USA
George E. Miller and Mare Taagepera

This chapter tells us how a successful training programme was developed for elementary and middle school teachers involving local industries. The formation of a Science Education Advisory Board, bringing together industrial managers, scientists and community representatives, strengthened and expanded the programme. The authors describe how, from a very simple teacher training programme, the project was enlarged, adding many successful sub-projects, of which *The Orange County Science, Technology and Society Network* is just an example. This specific sub-project aims to open and form permanent communication lines between the various social segments to enrich and provide a more meaningful science curriculum. Participants of this programme have also the opportunity to reflect and discuss, once a year, the future developments in science research and education.

Unindus: University-Industry Interaction Programme
University of Sao Paulo, Sao Paulo, Brazil
Reiko Isuyama, Peter W. Tiedemann, Gordon C. Fettis, David J. Waddington

This chapter describes a project based on the development of teaching materials for undergraduates, emphasising issues from local chemical industry. This work is being developed in collaboration with the Department of Chemistry at the University of York, UK. Several case studies are described in this chapter. The storyline of each unit is carefully discussed with industrialists in order to give a flavour of reality to the teaching materials. This project started with the production of teaching materials for university students and was expanded to involve the chemistry teaching in schools. The experience accumulated, during five years, allowed the members of the project to produce a completely contextualised chemistry course for TV.

We might finish this short introduction by pointing out the characteristics that are shared by the five projects described here, but we will not do so, because we would like to invite you to do this task. You certainly will identify the points which are common to all these initiatives dealing with curriculum innovation.

Peter Tiedemann
Reiko Isuyama

Bringing Industrial Chemistry into the Classroom: The Israeli Experience

Avi Hofstein and Miri Kesner

Department of Science Teaching
The Weizmann Institute of Science
Rehovot 76100, Israel

December 1994

A chapter in the book "Bringing Industrial Chemistry to the Classroom" (1995)

Bringing Industrial Chemistry into the Classroom: The Israeli Experience

Introduction

It is reasonable in the 90s, that new science curricula should enable students to apply scientific knowledge to more comprehensive and interdisciplinary problems that they encounter within their immediate environment[1]. It has been suggested[2] that developments in science education should include some of the following aspects:

- Concern for systematic interdisciplinary thinking with an emphasis on decision making skills.
- Specific connection to current issues and concerns.
- Whenever possible, case studies should be based on local industries and take into account physical features, agricultural concerns and other resources.
- Provisions for the teacher to select the most relevant issues for his/her students.
- Moral and ethical dimensions that accentuate the importance of science studying.

We, in the chemistry group at the Department of Science Teaching at the Weizmann Institute of Science, worked on the assumption, also advocated by Johnstone[3], that students pay more attention to their studies if the subject matter they learn seems to be useful and relevant. It is suggested, that if students choose to learn environmental topics such as industry, ecology and health, their motivation to study science, in general, and chemistry, in particular, will be increased.

In recent years, goals for learning chemistry have been expanded to meet with students' interests and ability[4, 5]. To date, we are not only teaching chemistry in order to prepare students for a career in science or for university studies, but also to become future citizens in a society that is highly dependent on technological and societal manifestations. Kempa[4] suggested that future curricula in chemistry education should include the following six dimensions:

- the conceptual structure of chemistry
- the process of chemistry
- the technological manifestations of chemistry
- chemistry as a personally relevant subject
- the cultural aspects of chemistry
- the societal role and implications of chemistry.

It is suggested, that case studies in the chemical industry could provide the basis for implementing these six dimensions in the chemistry classroom.

Teaching chemistry without discussing the various aspects of the chemical industry ignores one of the most important features of modern life, and by implication, implies that technological achievements are not important[5, 6].

In addition, overemphasis of the hazards of pollution, chemical warfare, radioactive and chemical waste disposal by the media helps to create negative attitudes in the general public and among the young, as well.

In the context of high school chemistry, the goals of teaching a course on chemical industry are to[7, 8]:

- consider the basic chemical principles as applied to the production of chemicals on an industrial scale
- demonstrate the importance of the chemical industry to society and to the economy
- develop a basic knowledge of the technological, economic and environmental factors involved in the establishment of a particular chemical industry
- investigate some of the specific problems faced by the local chemical industry such as the location of industrial plant, supply of raw materials and labor.

Development and implementation of a course on industrial chemistry

Content

A course on industrial chemistry is offered in Israel for high school students who choose to major in chemistry. This course is an integral part of the chemistry curriculum. *Chemistry - A Challenge* [9], developed in the Department of Science Teaching at the Weizmann Institute of Science, as part of the curricular effort of the Israeli Science Teaching Center.

This curriculum is now taught in Israel, in the majority of high schools, in grades 10-12 (ages 16-18).

The case study method was adapted for the development of units based on the chemical industry. This method enabled us to incorporate and integrate many of the features affecting production in a chemical plant, and to describe real situations and actual problems that exist in the chemical industry.

Our approach was to develop a series of individual industrial courses built on the gradual introduction of industrial considerations, new concepts and actual problems in chemical industry. This course was planned to be taught following the general basic chemistry course and to be related, as much as possible, to the students' scientific background.

The development of industrial case studies[7, 8] was started at the end of the 70s.

The first teaching unit, *Chemical Plants in Israel,*[10] dealt with three different industrial case studies. These units were supposed to give a comprehensive overview of industrial considerations, specifically, highlighting those of the Israeli chemical industry. Actually, each industrial case study was superficial and touched upon only a few problems which are important to the industrial chemistry.

Criteria for selection of case studies

On the basis of experience gathered during the first generation of the implementation of industrial case studies[7, 8], the second generation of industrial chemistry curriculum development and implementation was started in 1987.

Criteria used to select the plants that served as the basis of the industrial chemistry case studies were as follows:

- The chemical industries should have local importance, are based on local raw materials and are economically viable.
- The chemistry concepts and processes underlying these industries are based on students' knowledge and should be as comprehensive as possible.
- The industries selected are from different locations in the country and are not far from where the industrial chemistry case studies are taught
- The particular industries should be willing to cooperate and provide help both in the developmental and the implementational stages of the case study.

With these criteria in mind, two case studies, describing two different industries in Israel, were developed. The first *The Story of the Haifa Chemicals Plant*[11] is based on a fertilizer plant, which is located near Haifa Bay on the Mediterranean Sea in the northern part of the country.

The processing plant is centered on the production of the double fertilizer, $KNO_3(s)$, using the following process:

$$HNO_3(aq) + KCl(s) \rightleftarrows KNO_3(s) + HCl(aq)$$

Nitric acid is a product of the catalytic oxidation of ammonia and potassium chloride, or Potash. It is harvested from the Dead Sea.

The second case study *Bromine and Bromine Compounds*[12] deals with the production of bromine and its compounds near the Dead Sea in the southern part of the country. The Dead Sea is the lowest lake in the world at 360 meters below sea level and has the highest concentration of bromide ions in the world. Bromine and its compounds are important for a variety of uses, such as flame retardency, antibacterial activity and pest control. The case study describes the geology of the Dead Sea and its high content (330g dm^{-3}) of magnesium, sodium and potassium chloride and bromide salts. The uniqueness of the geographical conditions and the high concentration of salt (about a 6M solution) have influenced the development of an important industry based on the products of bromine and bromine compounds.

Bromine is produced from a solution of magnesium bromide using chlorine as an oxidizing agent:

$$2Br^-(aq) + Cl_2(g) \rightarrow Br_2(l) + 2Cl^-(aq)$$

More than 120 different bromine compounds are produced using many different production methods.

Figure 1 is an illustration of the overall components of the interdisciplinary approach of the case study entitled *Bromine and Bromine Compounds*[(12)].

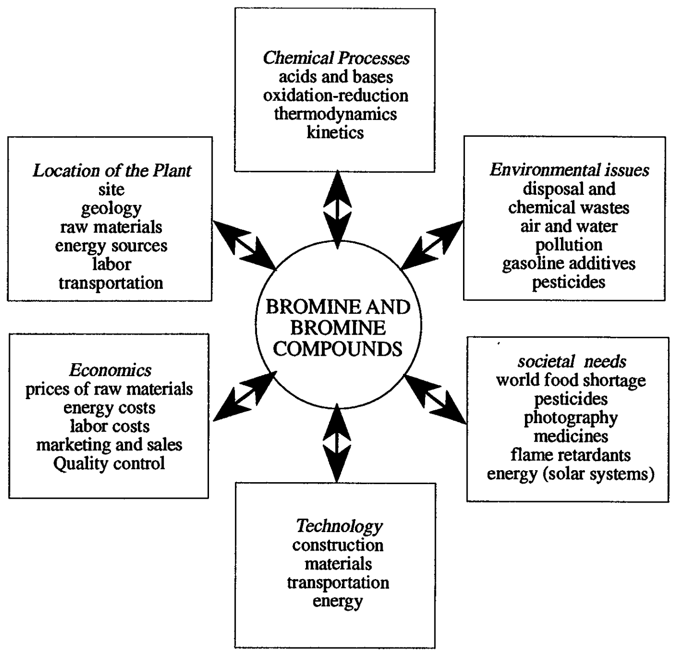


Figure 1: Illustration of the components involved in the case study *Bromine and Bromine Compounds*[12].

When presented with these two case studies, students are exposed to the particular details of the specific plant, the special language used in the chemical industry, as well as to the technological, economical and chemical aspects involved.

Figure 2 illustrates the general outline used in the presentation of both of the industrial case studies described:

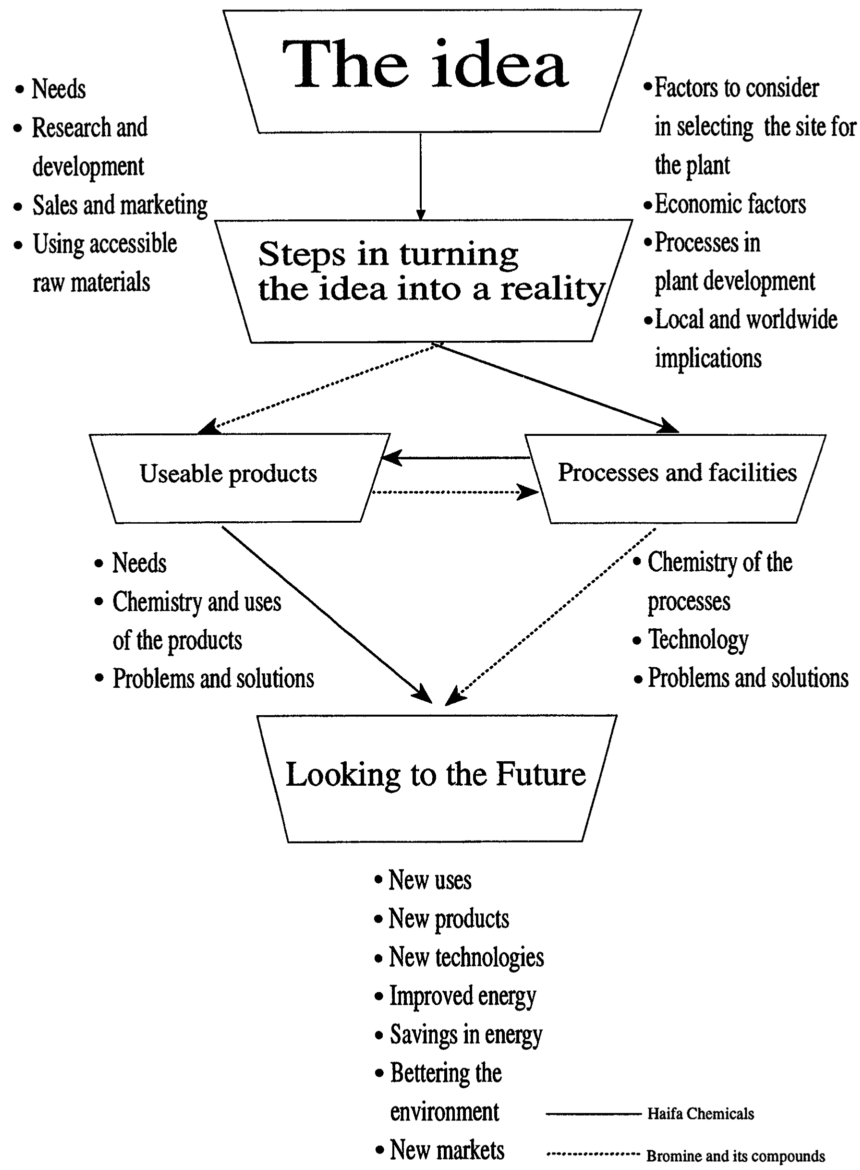


Figure 2: Diagram of the general outline used in the presentation of the industrial case studies.

The following outlines the teaching unit *The Story of the Haifa Chemicals Plant*

Chapter A. Background behind the plant

1. The concept behind the plant
    a. taking advantage of available raw materials
    b. why fertilizer?
    c. why potassium nitrate?
    d. elements essential for plant growth
    e. properties of potassium nitrate fertilizer
2. Turning the concept into reality
    a. selecting the site for the plant
    b. stages in turning the concept into reality
    c. economic factors relating to establishment and the plant.

Chapter B. The production process

1. The production facility of nitrous acid
    a. overview
    b. nitrous acid production process
    c. the catalyst in the process
    d. building materials used for construction of the nitrous acid facility
2. The production facility of potassium nitrate
    a. overview
    b. reaction system and separation of layers
    c. products
    d. building materials used for construction of the potassium nitrate facility
3. The production facility of phosphoric acid
    a. phosphate and its processing
    b. extraction of phosphoric acid
    c. industrial process for production of phosphoric acid from the starting solution
    d. problems of waste disposal-sludge
    e. building materials used for the construction of the phosphoric acid facility

Chapter C. Products and their uses

1. Potassium nitrate
2. Phosphoric acid and its products

Chapter D. Looking Towards the Future (ways for development, new products, new technologies, new uses etc.)

Appendices

A. What is a patent?
B. The nitrogen cycle in nature
C. Factors determining the rate of reaction
D. Simulated laboratory experiment of the oxidation of ammonia and production of nitrous acid
E. The Haber process
F. Experiment: Distribution coefficients
G. Simulated experiment for the production of a fertilizer

Questions

Cooperation with local industry: The establishment of the Chemical Industry-Education Center

The successful development of a course on industrial chemistry requires the active cooperation and participation of the industry under study. Support of the local industry is important in both the developmental stage as well as during implementation of the case study in the classroom.

Nowadays, chemical industries in Israel realize the importance of cooperation with the education system, in order to:

- encourage students to study chemistry in general, and industrial chemistry, in particular;
- try to encourage greater numbers of talented students to pursue careers in chemical industry which has suffered from a shortage of personnel in recent years;
- try to improve the image of chemical industry by demonstrating the importance of industry to the economy and society and its efforts to solve environmental hazards;
- educate tomorrow's decision makers, so that they will gain a greater awareness and a more balanced view of industrial issues.

There is no doubt that creating an active relationship between schools and industry is an important aspect in the implementation of the industrial case studies. Thus, a Chemical Industry-Education Center has been established in the Department of Science Teaching in the Weizmann Institute of Science. This Center is funded by the Chamber of Chemical Industry in the Israel Manufacturers Association and by Israeli Chemical Ltd. (ICL).

The main goals of the Chemical Industry-Education Center are to:

- provide up-to-date information about industries to teachers in high schools, programs for higher education and colleges;
- give information on resources and facilities provided by industries and various trade and professional bodies for teachers ;
- establish and maintain a data bank of sources of information for teachers about the industry;
- develop and produce relevant publications and educational materials where gaps exist and to encourage companies in the industry to help;
- provide opportunities for better communication between industrialists and teachers and to give industrialists a better insight into teachers' needs;
- organize industrial visits and lectures from experts in the industry to give teachers and students a better understanding of the industry;
- set up a library of films, books, computer programs and other materials that could be used in the classroom.

Some outcomes of the Center

Most of the big Israeli chemical companies, such as those dealing with petroleum chemistry, electrochemistry and medicine, have recognized the importance of encouraging a two way flow of information between the company schools. Companies host teacher and student visits and provide information and materials that can be used by the chemistry teacher. Through our Center, in the past four years, approximately 7000 students and 400 teachers have visited companies involved in the chemical industry.

Another joint activity of ICL and the Chemical Industry-Education Center is the preparation of lecture kits dealing with important chemical industries. These kits include overhead transparencies and a lecture guide. These are used as a basis for lectures given to chemistry classes by engineers and scientists from various chemical industries. Another activity which has been started recently, is the preparation of a collection of data sheets about the large chemical industries. These will serve students who are interested in obtaining information for individual or whole class projects.

The Center has also prepared a data source book(13) which includes important information on chemical substances produced by the main chemical industries in the country. Another source book(14) about important chemical plants serves to help teachers prepare their classes for visits to industrial chemistry plants, and gives relevant information on important industries, to guide teachers in the incorporation of industrial examples and issues into the regular teaching program.

Implementation of resources into teaching programs

Introduction

Teaching industrial chemistry, based on the goals described above, must be accompanied by intensive and comprehensive inservice training programs of chemistry teachers. Traditional training of chemistry teachers at the university or teachers' training colleges hardly touches upon the applications of chemistry, in general, and those of industrial chemistry, in particular. Even in the rare cases where teachers have an appropriate background, up-to-date information on industrial chemistry is not readily available. For this reason, many teachers feel insecure in discussing the economic, technological and environmental issues and manifestations of a chemical plant. Teachers do not feel competent to handle the many facets that such an interdisciplinary program touches upon and, as a result, are reluctant to teach such courses. In addition, most teachers regard their major task as to supply knowledge in the cognitive domain, namely, teaching chemistry concepts.

To train teachers to successfully implement both case studies, short intensive courses were conducted. These courses were required to alleviate the shortage of trained teachers able to cope with the many facets included in these units.

Regular teachers' training

The inservice training courses included the following components:

- Broadening teachers' knowledge of the social problems, political issues, and technological and environmental facts underlying the chemical industry
- Presenting an interdisciplinary approach to teaching industrial chemistry
- Demonstrating the application of chemical processes and principles in the chemical industry
- Using unique instructional techniques in teaching industrial case studies
- Planning and participating in industrial visits

Table 1 presents a summary of the topics included in a three day inservice training course aimed at acquainting teachers with various aspects of industry. Innovative teaching methods are also presented[15].

Chemical concepts	Technological aspects	Economic aspects	Other aspects
Chemical properties	Raw materials	Production cost	Research & development
	By products	Fixed, variable cost	Location of plant
Reaction: reactants & products & conditions	Reaction rate	Break-even point	Transportation
	Material balance	Supply and demand	Manpower
	Heat balance	Energy cost	Licensing
Bonding & structure	Output	Profitability	Patents
Solvents & solutions	Recycling	Marketing & sales	Safety
Oxidation-reduction	Recovery	Conversion & yield	Quality control
Acid-Base reactions	Flow chart		Environmental issues
Stoichiometry	Pilot plant		
Equilibrium	Scaling up		
Thermochemistry	Batch or continuous		
Thermodynamics	Waste disposal		
Free energy	Construction material		
Kinetics	Separation techniques		
Catalysts			

Table 1: Topics included in a three day inservice training course

Intensive inservice training of chemistry teachers; training teachers to vary their classroom practice.

It has been suggested[16] that varying classroom procedures, by using a variety of instructional techniques, is probably one of the most effective ways to enhance the student's intrinsic motivation to learn science. There is no doubt that teaching industrial case studies, with an interdisciplinary approach provides teachers with a wide range of opportunities to use different instructional techniques.

While teaching such case studies, one can:

- perform simulation games
- do project work
- set up classroom and group debates
- assign cooperative tasks to small groups
- use information from the media, journals and newspapers
- visit industrial sites
- attend lectures presented by experts from the chemical industry.

To implement these activities, teachers need to have skills in various classroom procedures and teaching methods as well as organizational competence.

Our first attempt to improve teachers' ability and skills was to incorporate a variety of instructional techniques at a series of intensive workshops. Initially, seven chemistry teachers, known to be experienced, cooperative, creative and willing to improve their own teaching, who also contributed and shared ideas with other teachers, were chosen to participate in this unique program.

The main features of these workshops included:

1. Discussing findings of a study(17)regarding exemplary chemistry teachers. Exemplary teachers were those teachers characterized by an inspector and regional consultants as creating a satisfactory learning environment with a high percentage of their students deciding to enroll in advanced chemistry studies in high school. Exemplary teachers were characterized by their students as being sensitive to their needs, aware of their learning capabilities, keeping pace with the majority of their class, encouraging students to cooperate with each other, using methods which made their lessons more interesting and ask questions at a high cognitive level.

   The group was subdivided into groups that focused on teaching characteristics that could be relevant and effective in teaching industrial chemistry. Each group presented its conclusions before a final discussion was conducted. It was unanimously agreed that all characteristics stemming from temperament or disposition be omitted since they can not really be changed by any course or inservice training program. Conclusions of the teachers participating in the workshop are outlined below and included the wish to:

   - utilize various classroom procedures and instructional techniques as detailed in figure 3
   - emphasize the relevance of chemistry to society and everyday life as part of the normal teaching procedure
   - challenge students with cognitively demanding tasks, problems and questions.

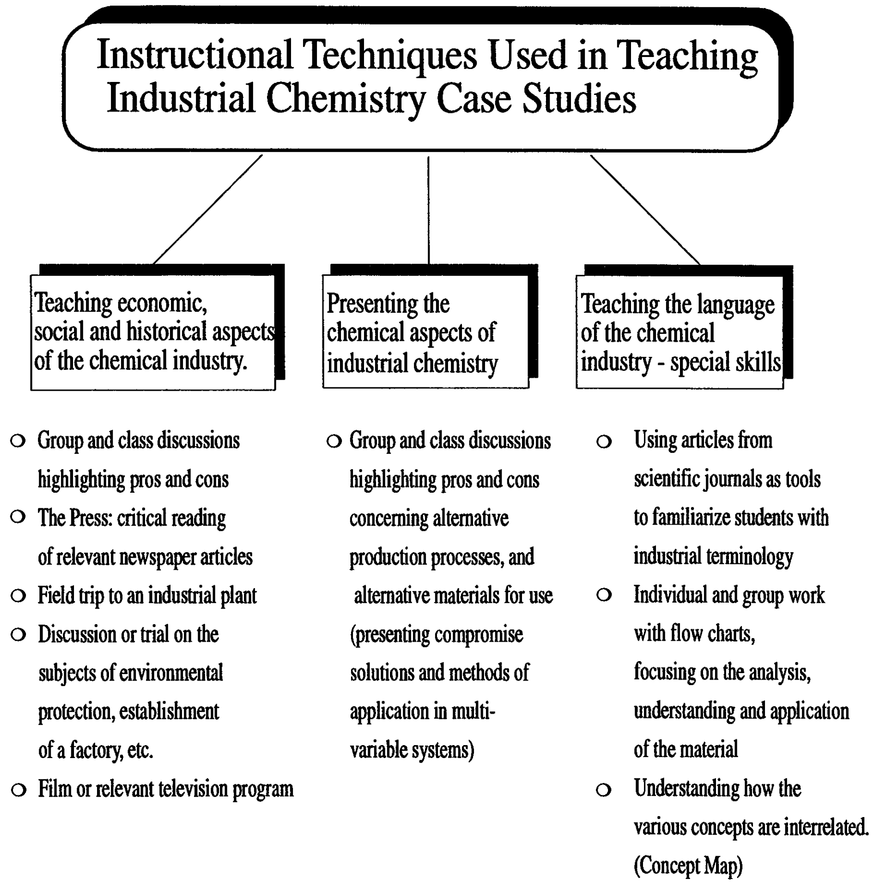


Figure 3: Detailed presentation of the teaching methods suggested by teachers participating in a series of intensive inservice training.

2. The group discussed the instructional techniques they found effective in teaching topics in industrial chemistry. Ways and methods to improve these techniques were designed. Among the recommended instructional techniques suggested were cooperative small group discussions, individualized worksheets, using information from the media and newspapers regarding industry and the environment and role playing activities.

3. The group was also involved in the planning and development of short learning assignments to be implemented in classrooms in which industrial chemistry is taught. However, these were mainly developed during the implementation in the classroom. For example, a simulation activity was designed in which the students played the roles of board members, citizens and municipal delegates, attending a board meeting at which they are told of a fire in the production facility of the plant. Students received all the relevant information, to which they added their own data during the activity, forcing them to make practical decisions.

In conclusion, a selected group of teachers became involved in the development of teaching instructional methods to be used in the newly developed industrial chemistry teaching units.

The materials produced by the group were then tested in the classroom and the final products were presented to more teachers in two ways:

- As the basis for other intensive workshops. Thus, more teachers could experience an intensive workshop which may change and better their teaching ability more effectively than a regular inservice training program. In addition, it would be possible to continuously develop and improve the new teaching methods.
- As a final product, for use in regular short inservice training courses for all teachers. By including all the updated, newly developed teaching methods in the regular inservice training programs and in the teachers' guide(18), it may be possible to improve the teachers' ability to teach industrial chemistry even when attendance at workshops is not possible.

It should be mentioned that in the beginning most of the teachers were reluctant to teach the subject. Direct quotes from some of the teachers are as follows:

"The industrial subject appeared to me to be overwhelming to teach. After the inservice training course I am stimulated to study the subject and it actually seems to me to be one of the most important subjects in the whole curriculum."

"After the training it was so easy for me to get prepared for teaching in class. Suddenly things appeared to be much more organized. I could read the book easily, and understood all of the different aspects."

"Students who were quiet the whole year, suddenly began to be involved".

"The students were very much interested in the chapter...they said that for that chapter alone it was worth studying chemistry...and, as for myself, it was also a way to revise the whole chemistry curriculum...and it was very important too, because the subject prepares the students for the future ..."

We were able to observe that having teachers involved in the planning and implementation of the curriculum decreased their anxiety and reluctance to teach new concepts and subjects and motivated them to use new teaching techniques.

Visiting an industrial chemistry plant

Purpose

In a review article(19) it was observed that outdoor activities provide a unique learning environment. Visits to museums, national parks and geological sites provide an effective educational situation that supplement regular teaching methods used in the science classroom(20,21).

The objectives for conducting a visit to an industrial chemistry plant(8) are to:

- demonstrate the applications of chemical concepts and principles already learned in the classroom
- illustrate processes by which products are manufactured in the chemical industry
- emphasize the importance of scientific research in developing industrial processes and products
- develop an awareness of the engineering and technological aspects of the chemical industry
- demonstrate the importance of the chemical industry to the economy of the country.

Such visits may also be planned as an interdisciplinary learning experience with the cooperation of biology, geography and economics teachers.

Planning and taking part in a field trip

Guidelines[14, 22] for teachers were prepared in our Center to make visits to industrial plants more effective. These guidelines helped teachers to prepare for the trip on several levels: administratively, in pre-trip orientations of the students and in post-trip activities in the classroom. In addition, the Chemical Industry - Education Center (CIEC) has helped schools in the preparation of industrial plant visits by collecting background materials from various industries, relevant articles from newspapers and magazines and preparing worksheets for the students. These materials are sent to schools based on the plants they plan to visit.

Factors[20, 21] have been identified that are influential in what they call the "novelty-space" of a field trip. "Novelty space" is the degree of familiarity with the field trip site; this factor can be reduced by prior preparation towards the visit to the chemical plant. The smaller the "novelty-space" is, the greater the benefit obtained from the visit.

Guidance regarding all aspects of organization of visits to the plant, optional ways for preparation and summative methods, must also be an integral part of all teachers' inservice training courses. We have found that the inclusion of such visits in inservice courses as well as discussions regarding industrial chemistry plant visits are stimulating and effective ways for encouraging teachers to integrate visits with teaching the industrial chemistry case studies.

The following are some of the guidelines for planning and executing a field trip to an industrial chemistry plant:

1. The visit should coincide with the subject matter taught at that time.
2. Objectives of the field trip must be clear to the students before the trip. Background materials prepared either by the industry they are about to visit and/or by the Chemical Industry-Education Center should be distributed to the students. These may include a flow chart of the processes to be observed or a list of questions to be answered during and after the visit.
3. Prior to the visit, students must be informed about safety and behavioural rules during the field trip.
4. The teacher should be in contact with the guide provided by the chemical plant, prior to the visit to inform him/her about the background knowledge and special requirements of the visiting group.
5. Upon return to the classroom, the teacher should summarize the visit. S/he may answer questions that the students raise and ask some questions of his/her own. A quiz about specific aspects of the visit or a student opinion questionnaire should also be given. All these have been demonstrated to be motivating tools as well as provide feedback for future visits.

Successful planning will lead to a successful visit. The personal cooperation between schools and industry, which starts in such a visit, may often extend into other areas such as supervision of students' small projects on industrial chemistry topics, loan of equipment to schools, preparation of learning materials such as flow charts, slides, etc. and, of course, future visits by other classes. Feedback is usually given by the teachers to the CIEC and to the plant.

Assessment and Evaluation

Achievement tests

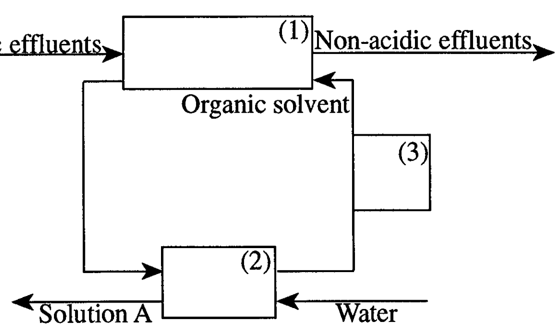
Each year approximately 6000 students, who choose to major in chemistry, take the matriculation examination, the Bagrut. Each student must answer one question about one of the two case studies described earlier. Students must be familiar with understanding chemical processes as well as interrelated economic, technological and environmental aspects.

A sample question taken from the 1991 Bagrut exam, given to students who selected the *Haifa Chemicals* case study, is as follows:

Many chemical processes yield effluents that are acidic. These effluents are usually treated by the addition of a base. Effluents that contain sulfuric acid are treated by the addition of calcium hydroxide, $Ca(OH)_2(s)$. This process produces a solid substance.

A. *i. Write the equation of the process.*
ii. Note two reasons for the use of calcium hydroxide in this process.

An additional method for treating acidic effluent is by removing the acids. The following is a schematic diagram of this kind of process.



B. *i. What process is carried out in Facility 1?*
ii. Why is the process carried out during an opposing flow?

C. *Note three properties that the organic solvent must possess.*

D *What process is carried out in Facility 2, and what is its purpose?*

E. *Facility 3, a distillation facility, is operated only occasionally. What is its role? Explain.*

F. *What special requirements are necessary for the substances used and for building these facilities? Explain.*

G. *i. What are the components of solution A?*
ii. Note two advantages of treatment through removal of acids, in contrast to treatment by the addition of bases.

A sample question taken from the same of 1991 Bagrut exam, given to students who selected the Bromine case study is as follows:

Below is a list of carbon compounds and their structural formula:

Compound	**Formula**
A. Bromomethane	CH_3Br
B. Bromoethane	CH_3CH_2Br
C. 1-bromobuta-1,3-diene	CH_2=CHCH=CHBr
D. 1-bromopentane	$CH_3CH_2CH_2CH_2CH_2Br$
E. 1-bromopent-2-ene	CH_3CH_2CH=$CHCH_2Br$
F. 1,2-dibromopentane	$CH_3CH_2CH_2CHBrCH_2Br$
G. Pentane	$CH_3CH_2CH_2CH_2CH_3$

A. *Which of the compounds listed is most combustible? Explain.*

B. *i. Which two of the compounds listed can be used for extermination of ground pests?*

ii. What properties make these compounds suitable for this use?

C. *Which of the compounds listed above can be used as active flame retardants in the preparation of non-combustible polymers? Explain.*

1 bromopentane is used in industry as a solvent and as an intermediate substance in the production of a variety of compounds. It can be produced in two ways:

1. from a suitable alcohol

2. from a suitable alkane

D. i. Formulate equations for reactions 1 and 2, and specify the conditions required for each of the reactions.

ii Which of the methods is best suited for the industrial production of 1-bromopentane? Explain.

Measurement of affective domain

In the area of the affective domain, several studies were conducted regarding perceptions of both students and teachers. An example of one of the studies is described here in detail. Students' perceptions regarding the industrial chemistry classroom learning environment were investigated. For the purpose of this study a questionnaire consisting of a 44 items Likert-type inventory using a scale of 1-4 (where 4 is fully agree and 1 is disagree) was developed. Using factor analysis procedures, 8 factors (scales) were created.

The scales and sample items are presented in Table 2:

Factor (No of Items)	Sample items
Attitude and Interest (5)	The topics we learn are very interesting
Involvement (4)	Discussions held in the chemistry classroom involve many students
Relevance (7)	In our studies we learn how chemistry is part of our lives
Applicability (7)	I do not think that my industrial chemistry studies are important to my knowledge of general chemistry
Instructional techniques used in the class (9)	In chemistry class, we have many pros and cons debates
Difficulty (5)	Too many new concepts are taught in the chemistry lessons
Preparation to become a future citizen (2)	I think that chemistry studies will enable me to analyze various issues as a future citizen
Occupation possibilities (1)	During our studies of chemical industry we discussed job opportunities in this area.

Table 2: Questionnaire given to students regarding their perception of the learning environment in their chemistry classroom.

The questionnaire was administered twice (pre and post) to a group of about 500 students divided to three sub-groups into:

1. Students who had learned industrial chemistry and their teachers who had undergone a regular inservice training course (about 200 students from 7 classes).
2. Students who had learned industrial chemistry and their teachers had undergone the intensive and comprehensive training workshop series (about 200 students from 7 classes).
3. Students who had no exposure to industrial chemistry in the course of their chemistry studies (about 90 students from 4 classes).

Statistical analysis revealed that students who were not exposed to industrial chemistry found their chemistry learning less relevant and applicable compared to those who had studied industrial chemistry. Students who found the most relevance and applicability in their chemistry studies were those whose teachers had participated in the intensive workshops. These students also felt that their studies of industrial chemistry better prepare them to become future citizens as compared to students of the other two groups. This quantitative analysis was accompanied also with qualitative analysis.

Direct quotes from interviews with students are as follows:

"It is a very important chapter that includes many aspects related to our daily life."

"The chapter enriched my knowledge."

"It shows chemical principles in daily life."

"Very practical and not only theoretical."

"It teaches us things that can help us in the future, even if we don't study chemistry."

"It is interesting because it does not include theoretical concepts which is how we are usually taught, but also the advantages and disadvantages of industrial products and especially of materials used in daily life. It shows the importance of chemistry and it teaches us about chemical industry in our country."

"I recommend that other students study it because I found it to be interesting and it is also something you read in daily newspapers."

Evaluation of visits to the industrial chemistry plant

A study(8) aimed at evaluating the effectiveness of the industrial visits was conducted. One school was chosen as a model for this study and it was repeated for three years with different groups of students. Visits included four industrial plants in the southern part of Israel. All four plants are based on the production of simple chemicals extracted either from the Dead Sea or from mineral deposits. At the end of each visit, a questionnaire in three parts was given to the students. It consisted of a Likert-type attitude questionnaire, free response questions about the aims of the chemical industry and a general question asking about the students' impression of the trip.

The study showed that students considered that the visits were important, interesting and enjoyable. They stated that the trips added to their knowledge and contributed to their understanding of chemical processes. All groups were in favor of discussing the role of the chemical industry in the economy of the country. They also recommended that the school invite lecturers from the chemical industry and that posters and pictures from chemical plants be hung in the school laboratory.

They found that the most impressive aspects of the visit were:

- the large-scale production and physical size of the plants
- the application of chemical principles in industry
- the sophisticated science-based technology used
- economic aspects and the emphasis of the plants on export of their products.

During the course of this study, it was observed that the students' attitude toward the chemical industry increased favorably from year to year. Moreover, interest in the chemical industry significantly increased in the third year, due to the experience gained by the teacher and industrial companies, resulting in improved organization of the visits. Both teachers and students expressed their wish to participate in future visits.

Other studies(23) have been conducted more recently concerning the evaluation of teachers' and students' perceptions of the visits. The findings will be published later this year(15, 24).

However, students' responses were very much in favor of the visit to the chemical plant. The following are direct quotes of their responses to the field trips:

"It was an interesting visit...without it, we could have only talked about the subject matter and it would have been dry and dull..."

"The visit helps and is even necessary for the understanding of the subject and for the motivation to study..."

""The visit helped me to understand what a chemical based industry is and how it is related to daily life. It was fun...and also good to get out of the school routine..."

"....chemistry and the people who work in it now look more interesting to me ....".

Summary

We strongly believe that introducing industrial chemistry units and case studies into the chemistry curriculum can help achieve one of the most important goals of chemical education. That is to demonstrate to students that chemistry is not only pure but also applied. It is suggested that these case studies helped in demonstrating the relevance of chemistry studies to daily life and apply abstract concepts in chemistry to real situations. The complexity of the industrial considerations and the fact that not only chemistry but other disciplines, such as economy, technology and quality of the environment are involved demands very carefully planned teachers' training programs. Training must involve the teachers with the industrial world and with a unique way of thinking as applied to industrial problems. In addition, teachers must be given the tools to present the industrial case studies in a proper way to their students. An important part of the implementation in the classroom is the development of appropriate teaching methods. We also suggest that having teachers involved in the actual planning of the implementation of the curriculum decreases their anxiety and reluctance to teach new concepts and subjects and can motivate them to use new teaching techniques in their classroom.

It is highly recommended that visits to industrial plants be an integral part of the teaching unit. To have the maximum educational effectiveness the visits must be well planned and the students prepared in advance. Communication with industry is necessary for obtaining up-to-date information not usually available in books and could be accomplished by establishing a center that organizes industrial plant visits and is sensitive to teachers' needs. This center is also responsible for their training and guidance.

In conclusion, we have tried to formulate the science curriculum of the future using the multidisciplinary case study approach, including visits to the industrial plants. The use of appropriate teaching methods is an effective way to create a future generation of citizens who appreciate the capabilities of the chemical industry and its technology. More students are aware of future job possibilities and education in the chemistry and industrial chemistry. Even those students who will not pursue these studies will be able to appreciate its complexities and relevance in both personal and societal levels.

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An example from the case study " Bromine and its compounds"

It is a small part out of the chapter "Production processes" that starts with a laboratory experiment and scales up to the industrial process.

E.2 Preparation of bromine in the laboratory

When the chemist discovers a process in the laboratory that can serve as an idea for a large scale industrial process, he must first carry out laboratory experiments. To do this, he must build an experimental system that resembles the production system as closely as possible. He must test the various steps in the process very thoroughly. The test tube reaction in which bromine was formed (most of the bromine dissolved) is only the beginning of the complex process involved in moving from the idea to the practical steps leading to production of pure bromine. In addition, to produce bromine in a test tube required preparation of chlorine which was then used to react with the bromine ions in solution. Every experiment to separate the bromine from the solution requires planning of additional steps that must be thoroughly researched.

Let us examine how it would be possible to build a system like this that will include all the necessary components mentioned. This system would need to include 3 steps:

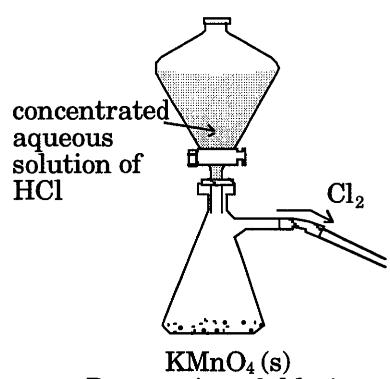
a. Preparation of chlorine
b. Reaction yielding bromine
c. Separation of bromine

Step 1: Preparation of chlorine

There are several laboratory methods for production of chlorine. In the method most commonly used, a concentrated solution of hydrochloric acid reacts with potassium permanganate crystals:

$$4H_3O^+(aq) + 3Cl^-(aq) + KMnO_4(s) \rightarrow 1\tfrac{1}{2}Cl_2(g) + MnO_2(s) + K^+(aq) + 6H_20(l)$$

as described in the following diagram:



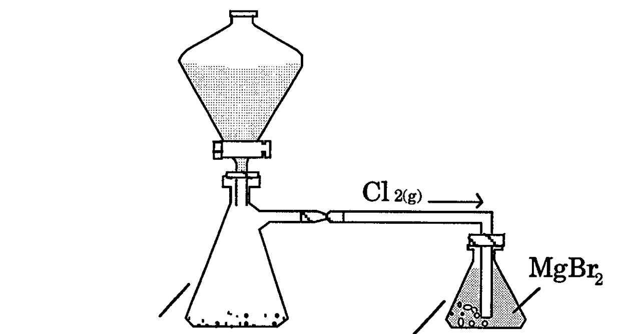
Preparation of chlorine

The chlorine produced can be channelled directly into the bromide solution.

What are the advantages and disadvantages of channelling the chlorine directly into the bromide solution, as opposed to the method described earlier? (i.e. Preparation of the required amount of chlorine and its subsequent transfer from the storage vessel to the bromide solution?)

Step 2: The reaction yielding bromine

Channelling the chlorine directly into the bromide solution is a simple and efficient method for carrying out the bromine-forming reaction. Therefore it is possible to build a combined system:



We would expect that bromine, which has non-polar molecules, would not dissolve readily in water. However, observing, the reaction we see that the color of the solution becomes more distinct and increasingly orange-brown, while very little bromine gas can be seen. The dissolution of the bromine in the aqueous solution can be explained by formation of a very soluble complex ion.

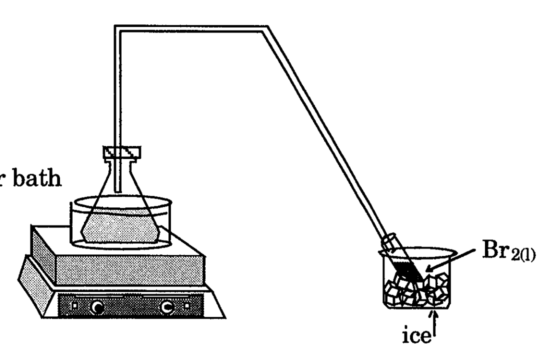
$$Br_2(aq) + Br^- \rightarrow Br_3^-(aq)$$

For the direct reaction: $\Delta H < 0$

The bromide ions bind the bromine molecules. Thus, in order to release bromine, one must drive the reaction in the direction of free bromine. Can you suggest a method for removal of the bromine from the solution?

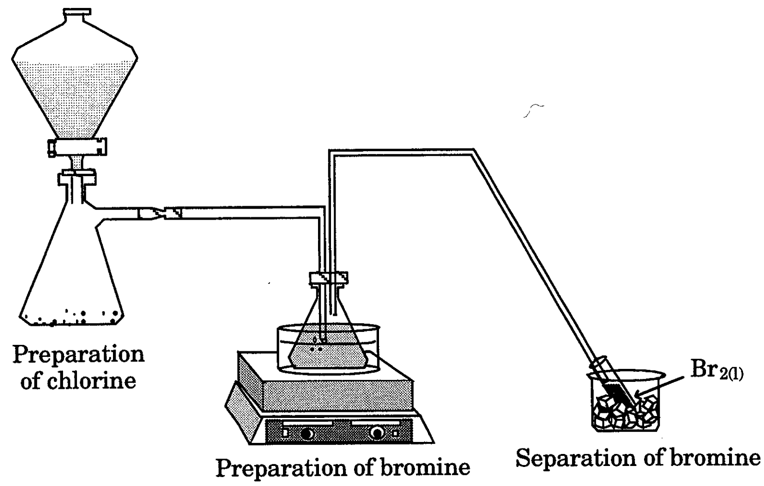
Step 3: Separation of bromine

The bromine can be released from the solution by heating. The entire quantity of chlorine can be directed into the bromide solution, and only after the reaction is complete should the solution be heated to the temperature at which bromine vapors are released. The bromine vapors emitted from the solution can be condensed by directing them into a test tube placed on ice (or on a mixture of ice and salt in order to further lower the temperature).



Separation of bromine

All the steps detailed above can be combined into a continuous process: the chlorine is directed into a heated solution of magnesium bromide, and the bromine vapors that are released are directed into a cooled test tube.



Observation of the process reveals that water vapors are emitted together with the bromine vapors, and that bromine and water are present in the test tube after condensation. After some time the bromine, which does not dissolve readily in water (this time the water does not contain bromide ions) forms a separate layer of the characteristic brown orange color.

E.3 From Laboratory Experiment to Industrial Production

The process that was developed for industrial production of bromine is based on the same idea that serves as a basis for this experimental system. However, it is important to note that in converting the laboratory process into an industrial process, many new problems arise.

Most of these problems result from the differences in quantities required for laboratory-scale versus industrial-scale production. In the laboratory, substances are usually prepared in small amounts, while the industrial process involves much larger quantities. We will detail the major factors impacting on the move from laboratory to industrial scale production, and will discuss the problems created by the differences in quantities involved. We will review some of the solutions that have been developed to deal with these issues in the bromine production process. These problems are universal to all industrial processes; the solutions naturally vary depending on the substances involved and their specific properties.

The Chemical Industry Education Centre
– a UK industry-education partnership

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October 1995

History and aims of the Centre

The Chemical Industry Education Centre, CIEC, was established in April 1988 as a joint venture between the University of York and the Chemical Industries Association (CIA), the UK trade association for the chemical industry.

The Association recognised that although certain major companies were providing educational services, there was still a need for a central service to provide for schools, up-to-date and authoritative material on the chemical industry in a form suitable for the classroom. This view was reinforced with the introduction of a new National Curriculum for England and Wales which features industry throughout the curriculum, justified by the first National Curriculum Council Chairman and Chief Executive:

> "Education for economic and industrial understanding is an essential part of every pupil's curriculum. It helps (pupils to) understand the world in which they live and prepares them for life and work in a rapidly changing world."(1)

The Association invited universities to bid for a new Centre, the Chemical Industry Education Centre, CIEC. One of the universities to submit a tender was the University of York which had by this time become an established centre for curriculum development, known for its pioneering work on courses in science. The CIA recognised that by establishing the Centre at the University, it would gain from the Science Education Group's reputation and contacts with teachers.

An agreement was drawn up between the Chemical Industries Association and the University. The University offers accommodation, services and active collaboration of its academic staff. The Association funds salaries of the core staff and direct costs, such as printing and postage.

In the early years of the Centre's existence, 35 companies donated monies to the base funds. The base funding was increased gradually and in 1995, a decision was taken that funding should come from core CIA funding rather than from voluntary donations from its member companies. In effect, all CIA member companies now support the work of the Centre.

The policy and overall control of the Centre are in the hands of a small management committee, with representatives from the Chemical Industries Association, the University, the chemical industry and schools.

The aims of the Centre are to:

- enhance the effective teaching of science and technology
- create enthusiasm for science in school students and children
- improve the level of understanding between schools and the chemical industry
- create a better understanding of the nature and role of the chemical industry within society.

The Centre achieves these aims by:

- offering a *specialist research and consultancy service* to industry. It also provides an *independent and comprehensive advice and information service* to teachers and schools throughout the UK.
- *designing, trialing, publishing and distributing teaching and learning packages* which illustrate industrial applications of the science and technology defined by the various UK curricula and which include stimulating, interactive science activities which develop skills needed by industry.
- *contributing to public understanding of science*, for example, by working with science museums and hands-on centres, to facilitate students' interaction with the galleries and exhibits and by presenting workshops and interactive displays at science festivals.

In addition, the Centre helps to meet the needs of both industrialists and teachers by:

- *training industrialists*

  to understand the implications of the new science and technology curricula

  to support and enhance teaching and learning activities in schools local to the site

- *training science and technology teachers*

  to make more use of industry as a resource

  to make most effective use of CIEC teaching materials

  to extend the number of teaching strategies they currently use.

Benefiting industry

CIEC contributes towards the formulation and implementation of the Chemical Industries Association's education policy, and at a more practical level, member companies come to the Centre for advice. This helps them to keep pace with changes in the education system and helps them to be better equipped to meet the needs of teachers and their students.

The base funding is essential to create the point of reference to enable industry as a whole to contribute to science education. However, without the support of companies that commission specific teaching packages or that host professional development courses the Centre would act as little more than as an advisory bureau. Thus, the Centre works closely with people within companies commissioning teaching resources.

By funding the production of teaching resources the industry's reputation can be enhanced because teachers and students are then able to make informed judgements about industry's activities. Students may be more inclined to follow science-related careers.

In this sense the work of the Centre complements the efforts of individual companies, such as BP's Link Scheme, which encourages BP staff to spend time in local schools:

> "as a result of concern about the drift from science among able school children when making academic choices, the scheme linked a company scientist or engineer with a local science teacher in order to help and encourage in any way they could."[(2)]

When first becoming involved in school science education, company representatives often approach the Centre and the following questions have to be resolved:

What age group does the company want to target?

Do they want a local initiative or a national one?

Do they want to produce a resource for teachers and students or organise an event?

How large is the budget?

How much involvement do they want in the initiative and who actually does the work?

Who has final control?

What is the company dead-line and what is feasible in this time scale?

How will the products be marketed?

Each of these questions will briefly discussed in this chapter.

What age group does the company want to target?

Large companies in the UK chemical industry have supported education in schools for many years. In the 1950s, for example, several companies had senior members of staff whose primary role was as school liaison officers. This work has grown steadily and now many companies are involved actively in primary and secondary education, in science and many other subjects.

When working at the secondary school level, the scientific ideas covered by a resource or activity can be sophisticated and certainly at the senior end of school, industrial processes can be modelled or aspects of scientific research introduced. Many students are more motivated to learn when they can see the relationship between the science they are learning at school and the science employed by industry to sustain and improve living standards.

In addition, companies feel that by contributing to the top end of the science curriculum, they can generate a greater interest in students to come and work for chemical and allied industries.

In reality most children base their career choices on experiences and contacts that they have had at a much earlier age.

Industry should also consider supporting primary education too, if they wish to enlarge the recruitment pool.

> "Industry is part of a social and physical environment within which primary school children grow up. They therefore should be encouraged to learn about the society and world around them. They should be helped to understand something of industry's structure and organisation."(3)

Younger children are still formulating their opinions. There is an opportunity for resources and activities to influence young people's perceptions of the usefulness of science and industry and also to consider the constraints they would wish to impose on industry and the products demanded by society, including how to manage the waste generated. For older students, resources and activities can encourage the use of scientific knowledge and understanding, acquired in school, to challenge views they meet from both pressure groups and company literature.

In the UK, primary schools have a legal obligation to teach science even though many teachers have little to no scientific education themselves. The resources and events produced can therefore be seen as part of the teachers professional development programme.

Many companies are beginning to understand these issues and the number of projects to support primary school science teaching at CIEC is now equal to the number of secondary school initiatives.

Local versus national initiatives

All of the publications from CIEC are distributed nationally. However there is a local component in the development and marketing of the resources.

At the beginning of each project a team of industrialists and teachers local to their sites are brought together to brainstorm ideas for the teaching package. Once the package is developed, sites are invited to host inservice training events for local teachers. These help to train the teacher to use the package, and where appropriate, to involve an industrialist in classroom or site-based activities.

CIEC is involved in organising inservice events for companies and other organisations throughout the UK. Most of these are aimed at local communities but some involve participants coming from anywhere in the UK.

Resource or event?

Events commonly supported by industry include site visits, careers evenings and mock interviews, work shadowing, placements and experience, lectures and presentations. Of these events CIEC:

- designs site tours which will both stimulate the students and support the science curriculum
- trains industrialists to communicate with the students with whom they come in contact.

The budget

Company budgets vary considerably from several hundred pounds (sterling) to thousands. Small budgets will buy an inservice event or can be pooled together to produce sufficient funds to commission a resource.

From the company viewpoint, developing a resource is more expensive than organising events but the impact can be much greater throughout the UK.

The following table gives an idea of the scale of various CIEC activities which can cost from a few hundred to several thousand pounds.

1 day inservice training event

2/3 inservice training days

Sponsorship of the CIEC Newsletter for schools (sent every 3 months)

Printing ca.1000 copies of a small teaching resource

Teacher/industrialist workshop at the start of a project

Development of, publication of, and training in using a teaching resource

A typical project takes a year from inception to publication. The major costs include the project teacher's time, trial costs, printing and buying time to get teachers out of school to help at the workshops. Occasionally a company commissions more than one resource at a time. The unit cost of a teaching package can then be reduced.

Company involvement and who actually does the work?

> "Ultimately, of course, it is the teachers who will convert all the ingredients into a sound education for our children. It is important then, that the array of material and ideas designed to help teachers is presented to them in a form which they will find really helpful."(4)

Most companies enjoy involvement in the development of the teaching packages. CIEC involves representatives from the companies at three critical stages in the development of the resource:

- Most projects are initiated with a workshop at which teachers of children of the appropriate age group work with industrial colleagues to identify suitable stories, either industrial or social, which can be used to introduce or reinforce, one or more important scientific concepts to be covered in the curriculum.
- After the project teacher has worked on the ideas arising from the initial workshop, the original team are brought back together to evaluate the treatment of their ideas.
- Finally, prior to school-based trials, the project teacher sends a copy of the package to the industrialists on the team to check the accuracy, once again, of the scientific and technological ideas contained in it.

This model emphasises the partnership CIEC has with its industrial and teaching colleagues but the burden of the development work remains with the Centre.

The teachers involved benefit from making contact with their industrial colleagues. This often leads to other local initiatives or exchanges of information. In return the industrialists are often surprised by the amount and quality of science taught in schools, especially at the primary level, and also get the opportunity to appreciate the numerous changes in the science curriculum and how it is taught.

Who has final control?

After all the trials and checks, the teaching resources are published by the Centre. CIEC retains copyright of the material which ensures its independence and in the minds of teachers gives it more credibility as independent and balanced material.

The companies which commission resource materials are acknowledged with a logo on the cover. The original design team of teachers and industrialists are also given credit in the introductory pages of the books. However, beyond this, the company is not mentioned again. The teaching notes and student worksheets will not directly refer to the company or mention that the processes discussed are taken from a specific site.

Some industrially-produced resources have been treated with some scepticism by teachers and students alike. CIEC ensures credibility by giving balanced coverage of the issues raised in a teaching resource. Some examples of such resources are given later.

What is the company dead-line and what is feasible to achieve?

Many companies assume that teaching packages can be churned out fairly swiftly. However, the average development period is a year. The fastest package CIEC produced took just five months but this was exceptional and the bulk of the work had been done by the company before they approached the Centre. To summarise, the CIEC resources are produced as follows:

brainstorming workshop
↓
first draft of the resource by CIEC project teacher
↓
second workshop to discuss and improve the resource
↓
drafting of trial version of the resource by CIEC project teacher
↙ ↓ ↘
safety check | company evaluation | CIEC evaluate
↓
school-based trials
↓
revision
↓
publication

This procedure ensures that resources meet the needs of teachers and are of high quality.

How will the resources be marketed?

The issues concerning marketing include:

- the shelf life of the material; the information and ideas are unlikely to date, even if teachers are slow to adopt material. For example, the *Essential Chemical Industry,*[5] one of CIEC's reference books, needs to be revised regularly in order to keep the data in it up-to-date. However, most of the teaching resources will have a shelf-life extending beyond 5 years providing the National Curriculum remains unchanged.
- the price: what can schools afford? CIEC sells the publications to schools. Some organisations and companies prefer to give away their productions free of charge. However, there is some evidence to suggest that this material is less highly valued than material which has been bought.

Towards the end of 1994, our marketing strategy was evaluated and it was decided to help publicise our work by obtaining bibliographical references in publications, maximising the use of contacts with other companies and professional or trade associations, publishing newsletters and organising workshops and seminars throughout the country.

Evidence suggests that teachers learn about resources from three main sources - articles, colleagues and training events:

- *articles* written by teacher and industrial users of the material or by the CIEC staff, often lead to a dramatic increase in sales of the CIEC publications which are the focus of the article. These articles appear in general educational newspapers, such as the Times & Guardian, but more often in specific science education journals aimed at either secondary and primary school colleagues. The chemical industry trade and company journals also like to carry articles which highlight the role a particular company or sector group has played in supporting science education and schools.
- *colleagues* provide some of the best networks for publicising material. There is nothing quite like hearing someone extolling enthusiastically the virtue of a resource or event they have experienced. CIEC, therefore, tries to maintain good links with all those who have had contact with the Centre, keeping them up-to-date with new publications, staff changes and other items through a regular newsletter.
- *training events* are by far the most effective way to pursuade newcomers to CIEC resources to make use of them to enhance their science teaching. Although it is costly and slow to reach large numbers of teachers this way, it is possibly the best method to ensure that the resources bought are also used. Training events are arranged through Local Education Authorities, chemical sites and a network of Business Education Partnerships.

Publications

The publications fall into two categories: one is *reference material* about either the chemical industry itself or its products, and the other, *teaching packages* which use industrial stories to prompt students to use their scientific knowledge to solve problems or make decisions.

Reference materials

The *Essential Chemical Industry,*[5] is a booklet, published by the CIEC and funded by the Salters Institute of Industrial Chemistry, which provides teachers and post-16 students with information about 70 chemicals or groups of chemicals. The topics are selected because they are in the A-level examinations which, in the U.K. are regarded by the universities as examinations for university entrance and because of their relevance to the curriculum giving a brief outline of the process and the underlying chemical principles. They also cover economic and environmental issues, tonnages produced and uses. Each entry is validated by a company that makes that material.

Partners in Science Education[6] is a directory of sites and organisations that support science education. *Industrial Encounters*[7], *On-Site*[8] and *Site Seeing*[9] are three publications which aim to assist teachers to develop contacts with local industries and identify the nature of the links they wish to establish and which improve the impact of a site visit. *Site Seeing*[9] is a series of three guides for plant visits by primary school children that concentrates upon safety, measurement and storage.

The two *Good Resource Guides*[10,11] are a collection of reviews aimed to help primary[10] or secondary[11] school teachers of science identify excellent teaching resources produced by industry. The resources include written materials, posters, videos, computer programs and interesting visits. Each review has been written and signed by a practising teacher who has used the resource with their students.

Teaching resources

The resources are designed with specific age groups in mind. The books include teacher's notes, background information and differentiated worksheets and indicate where there are opportunities for work on microcomputers. The learning activities include laboratory work, data interpretation, model making, numerical exercises, interviewing, creative writing, evaluation, oral reporting, poster presentation, group work, problem solving and decision making.

Over 80 teaching resources have been produced by the Centre in the last 8 years. The selection below is chosen to illustrate what can be done with resources produced in partnership with industry for different age groups.

Wearing Jeans[12] and *Hot Chocolate*[13] are two examples of units from a series of 12 units called *Making Use of Science and Technology*. This series had support from 6 chemical companies.

Wearing Jeans[12] (for 14 - 16 year olds) compares the stone washing techniques for fading denim with a biotechnology process using enzymes. The resource gives students the opportunity to investigate the specific nature of enzymes, the optimum conditions for their reactivity and how to control reactions. It also illustrates vividly how a new process can enhance the environment dramatically.

The final pages of this chapter illustrate how science is developed through the Wearing Jeans teaching resource.

Hot Chocolate[13] (for 12 - 13 year olds) is based on the true story of a confectionery company having problems from the effect of heat in the summer months on the chocolate. The problem was traced to transportation by road. The trucks were painted in the company's logo colours, deep purple and gold which absorb heat. Students investigate the relationship between colour and heat absorption and make recommendations to the company. The company has now sprayed the vans white!

Clean Science[14] is a unit which helps 11 - 14 year old students to understand how surfactants work. This unit was supported by a group of 5 companies with a common interest in surfactants. The most novel investigation includes the use of a 'paper clip' surface tensiometer inspired by studying the instrument used in industry. Despite its primitive appearance the paper clip version produces surprisingly good differentiation between different liquids, or between water samples with various surfactants added.

Exciting Science and Engineering[15] is a series of eighteen teaching units for 7 - 14 year olds. It is sponsored by British Petroleum. One unit, *Stone Engineering*[16] (for 12 - 14 year olds), uses the mystery of Stonehenge to investigate the principles of levers, ramps and pulleys. Another, *Shadow Play*[17] (9 - 11 year olds) introduces ideas about light and simple mechanics by the use of a shadow puppet theatre. *Cool It*[18] (9 - 11 year olds) and *What's the Solution*[19] (11 - 13 year olds) investigate energy transfer and solutions in simple industrial contexts and relate them to tasks, such as, cooking. All 18 units suggest roles for engineers to take whilst working alongside the teacher in the classroom. The roles are varied but each encourages the students to work with an engineer in a team or as partners.

As I have discussed above, more companies are now commissioning science teaching resources for primary schools. *Be Active - Science is Fun*[20] (sponsored by BASF), three teaching packs for 8 - 12 year olds, covers a series of ideas which relate to the business interests of BASF, plastics, colours and fine chemicals. *Smile its Science*[21] (sponsored by Exxon), another series of three units, broadened the scope of CIEC's work by taking publications into the 5 - 7 year old level. *Tidy and Sort*[22] introduces this age group to classification by sorting and separating simple objects which children might find at home. The context is set by a story book (pupil reader) in which twins are asked to tidy their bedroom. This theme of mixtures and separation is extended in a unit for older children (8 - 11) *Kitchen Concoctions*[13] (Sponsored by the Chemical Industries Association) into a consideration of what chemical reactions are and how can they be controlled.

As the UK education system broadens to give vocational courses more status, CIEC has responded by developing resources that can support these courses too. The largest project involves 9 health care companies and contexts are wide ranging, for example, caring for skin wounds, breast cancer drugs, tablet coating and piracy (protection against piracy and the consequences). This series is called *Chemicals for Healthy Life.*[(24)]

Other services

Inservice training

Another major activity of CIEC is provision of inservice training both for teachers and industrialists. This is extensive both in terms of the variety of training provided and in terms of geographical coverage.

Many of these workshops are built around the CIEC publications. So, in addition to the focus of the training, teachers have the opportunity to try out the resources. Where appropriate, teachers and industrialists work together.

Training provision is given to industrialists working with school students. This covers speaking to school audiences, organising site visits and how to work with a teacher to help support classroom and laboratory activities.

A fee is charged for these workshops which, where possible, is costed commercially.

Information service

A data service is offered to teachers, students and children looking for specific pieces of information related to the chemical and allied industry. This supports the reference book publications. Where there is a large number of requests about a topic the Centre endeavours to publish material to cover the subject.

Consultation service

The CIEC also offers a consultation service to companies and organisations that wish to produce their own educational material or to set up links with local schools. In the latter case the Centre will often facilitate meetings between the company and its local schools, provide training and in some cases help companies formulate their national/international policy.

Evaluation and evaluation tools

The Management Committee devotes one meeting a year to looking at long-term strategies and to ensure the objectives are still appropriate and that the range of CIEC activities are the best ones to achieve these.

The resources are a key part of the work of the CIEC, and so evaluation of their usefulness is built into the development model through the school trials. Following their publication other methods are used to evaluate the usefulness of the resources.

These include:

- a questionnaire which accompanies each order. The questionnaire asks how the teacher found out about the resource, who they used it with and to what extent they felt it was effective. Some of the respondents are interviewed by telephone.
- the resources are reviewed in appropriate secondary science education and primary school education journals.
- research projects are initiated to find out, for example, what further support primary school teachers need in order to teach science more confidently and competently.

The inservice training events also help to give an impression of what teachers' perceptions are of the materials. The participants at each event are asked to evaluate the training before departure in order to ensure that these events are meeting their needs.

Two research projects were initiated in 1995 which looked at the impact of CIEC resources on teaching science in primary and secondary schools. The primary school research project will run for three years and involves a CIEC project officer working with a number of schools each term. Using CIEC resources the officer and a teacher, team teach over 3 - 4 sessions. Prior to these lessons the project officer interviews the children and teacher to record their views about science and industry. Following the sessions, the interviews are repeated in order to establish whether a change of view has taken place and, if so, what it is.

A broader approach has been taken with the secondary schools. Teachers are being asked how they heard about the CIEC resources, what encouraged them to by the resource and how they use the resource. Those teachers who are introducing the resources into course work, rather than using them in club activities or as a source of ideas are being further questioned in order to establish what is required to implement the use of material in the curriculum.

The evidence suggests that the materials and services provided by CIEC are appreciated by those who know of them. A big challenge faced by the Centre is to find the most effective way to let teachers know what is available and then having the resources to respond to the increased demand.

Hopefully these research projects will help to identify how CIEC can better publicise the resources and encourage teachers to make more effective use of them.

Pages from Wearing Jeans is shown in the appendix of this chapter.

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WEARING JEANS

Synopsis

For a number of years it has been fashionable to wear jeans which have a faded look. Traditionally, the faded appearance has been produced by the manufacturer stone-washing the jeans with lumps of pumice stone. More recently, the effect has been simulated by using cotton-digesting enzymes. It is this process, and also the use of enzymes to de-size denim fabric, which is studied in this unit.

WEARING JEANS is intended for students in the 13 - 16 age range, but the unit may be extended for use with older students.

What the students do

- Observe the structure of denim fabric and the characteristics of indigo as a dye.
- Study cellulose and starch as natural polymers.
- Investigate the action of enzymes on these giant structures and determine the most effective conditions for using enzymes in the manufacture of faded jeans.
- Prepare a display which explains the manufacture of faded jeans and the advantages of changing to a process which uses enzymes rather than traditional methods.

Key ideas

- the ability of enzymes to catalyse reactions
- the effect of temperature and concentration on reaction rates
- the specificity of enzymes
- the structure of the natural polymers, starch and cellulose
- the natural and commercial role of enzymes

The unit provides opportunities to contribute towards the development of the cross-curricular theme 'Education for Economic and Industrial Understanding'.

Estimated timing

This unit provides a variety of activities and suggestions, and teachers should select from them to match existing schemes of work and the time available. The equivalent of two lessons of 70 minutes duration is sufficient to cover the core activities.

Practical 3. (60 minutes) Using an enzyme to fade denim

Students investigate the action of cellulase in fading denim. Details are on SAG 3 and the corresponding test sheets. Students work in groups of three or four. 6 cm squares of de-sized denim are required for this activity. Samples that are still damp, possibly after de-sizing larger quantities of denim, produce results in the shortest time. Instructions for de-sizing larger quantities of denim are in the 'Planning ahead' section of this unit. This class practical could be much simplified by having one large beaker containing sufficient denim samples for the whole class.

Industrial use of the cellulase enzyme requires a washing time of 45 to 120 minutes at the optimum temperature of 52 °C. However, since there is no requirement in school to re-use the enzyme, the cellulase can be pushed towards its limit by maintaining the temperature of solutions at 60 °C or higher. Enzymes are not deactivated at 40 °C. Detail of the effect of temperature on the activity of enzymes is included in Appendix 1.

At 60 °C, good results are obtained after 30 minutes. To save time, students should be provided with the hot solution of cellulase freshly made up for the beginning of the lesson. Note that pouring the hot solution into cold beakers will cause delay. The Technician sheets give the required concentrations and also contain brief notes on the stability of prepared solutions.

Students have not been given instructions on how to maintain the temperature at 60 °C. Time is limited and teachers must decide how the class is to achieve this. Heating beakers over Bunsens is difficult for students to control. The use of plastic washing up bowls as communal water baths is suggested. The temperature in the bowls is adjusted by the teacher stirring in boiling water from an electric kettle. Students working in smaller groups could use 2 litre ice cream containers as water baths.

Safety

Students will need to be supervised if the hot solution of cellulase is to be poured from a heavy beaker. Care is also needed in syringing off 10 cm^3 portions of hot solution when testing for simple sugars.

Those students who handle denim samples that are wet with enzyme solutions should wear protective gloves.

If time is likely to be a problem, it may be useful to have available a beaker containing samples of denim that have already soaked in cellulase for longer periods (or retain the samples and solutions used by previous classes).

Cellulose is difficult to digest due to the hydrogen bonding between the parallel fibres. The vigorous action of industrial washing machines cannot easily be reproduced on a small scale and frequent stirring of the beakers is important. Small squares of denim will tend to curl up so that the outer surface of the fabric is shielded from attack. Should this cause problems, the simplest solution is to fold the squares in half and staple the warp edges together.

Test A

A faded effect will not be obtained after only 10 minutes, even though indigo dye is beginning to be released from the denim squares. Students are not likely to observe a good effect until after 30 minutes. The appearance of faded samples improves after drying and is further improved by trimming off the frayed edges of the warp threads only.

Test B

The presence of sugars can be detected in the first 10 cm^3 sample that is syringed off after 10 minutes. A more substantial green deposit, eventually turning orange, will be obtained after 20 minutes. There is no need to wait for all the filtrate to run **through the filters** before **testing for sugars**. Solid indigo dye will be visible on the filter papers.

A washing up bowl containing soapy water is suitable for washing enzymes off the samples. After rinsing, samples may be dried with a hairdryer or on a hot radiator, or may be left to dry at room temperature.

Students should decide how long the enzyme needs to do its job. This will depend on the temperature used and how dry the de-sized denim was. Teachers could extend this activity by comparing enzyme action with the effects achieved by rubbing pumice stone on wet de-sized denim.

Practical 4. (60 minutes) Will any enzyme de-size denim?

Students test the effect of both amylase and cellulase on 5 cm squares of sized denim. Water is used as a control. Details are on SAG 4. The SAG 2 Test sheet is used again when testing whether or not the enzymes have removed the starch.

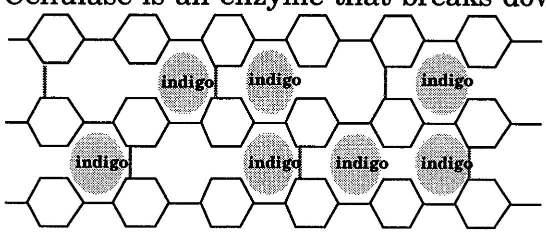
All solutions are used at 40 °C. Students could be asked how this temperature can most easily and safely be maintained. Students will find that enzymes are highly specific. Amylase will de-size denim, cellulase will not. Similarly, cellulase digests cellulose, but amylase will not. This latter case may be tested, but is more demanding of time.

The enzymes supplied are from microbial sources. They are not synthetic. Since the cellulase is a mixture of enzymes, it may contain small quantities of amylases that result in the unexpected appearance of traces of dissolved sugars in the test solutions.

SAG 3

USING AN ENZYME TO FADE DENIM

Cellulase is an enzyme that breaks down cellulose.

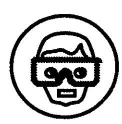


Cotton is made of cellulose.

Particles of indigo dye are trapped between the long chains in cellulose.

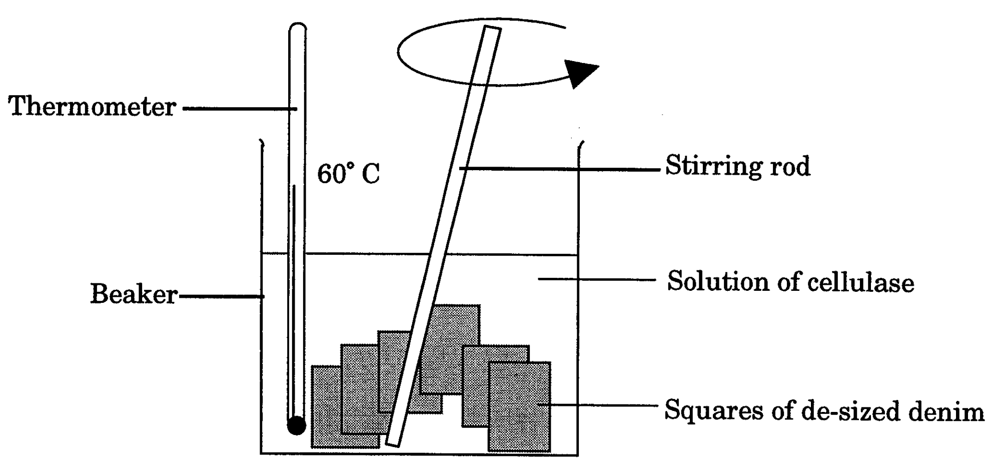
The enzyme splits up the long chains in cellulose into simple sugars. As a result, the indigo dye is released and the denim fades.

Find out how long the enzyme needs to do its job:

Wear eye protection 

1. Pour 200 cm^3 of cellulase solution into a 400 cm^3 beaker. Place 6 squares of de-sized denim into the solution.

2. Keep the contents of the beaker at 60°C for 30 minutes. Take care that the thermometer does not cause you to knock the beaker over. Stir the contents frequently.



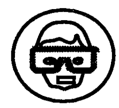
You will take samples from the beaker after 10, 20 and 30 minutes. Test A and Test B could be completed at the same time. Be ready to share out the tasks.

Time and heating costs are important in industry. Study the results and observations. Decide how long the enzyme needs to do its job.

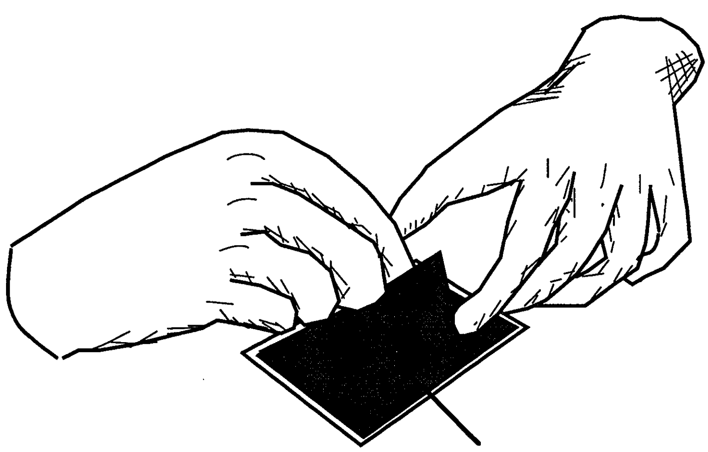
SAG3 **TestA**

HAS THE DENIM FADED ?

Denim jeans can be faded by using enzymes in industrial washing machines. You must simulate the effect of jeans, heavy with water, tumbling over and rubbing against one another. You can do this by rubbing one square of denim against another. Remember that enzymes may irritate your skin.

Wear eye protection  Wear protective gloves 

1. Use tongs to remove two squares of denim from the beaker. Squeeze excess liquid back into the beaker. Put the squares on a paper towel and allow them to cool for a few seconds.
2. Place one square with its darker side up. Wrap the second square of denim around your finger and rub it firmly across the first square of denim for about one minute. Use a circular rubbing motion.



Gloved hands

Denim square

Look for signs of producing a faded effect. You may see white areas, where the outside of the dyed threads has been broken down, but only if the enzyme has had time to do its job.

3. Wash the two squares in dilute detergent solution, rinse them well and allow them to dry. Keep samples for a class display.
4. Repeat the test, using squares of denim that have been in the enzyme solution for 20 minutes and 30 minutes. Record all your results and observations.

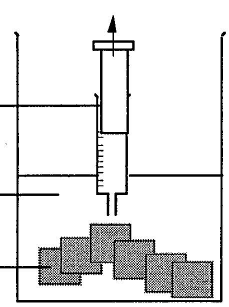
SAG3 **TestB**

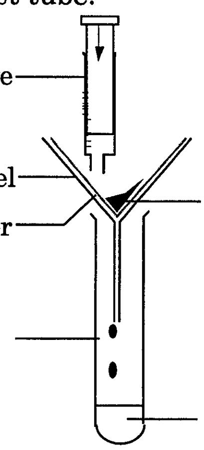
IS THE ENZYME WORKING ?

If the cellulase is beginning to work, simple sugars will be present in the beaker and indigo dye will be released.

Wear eye protection

1. Use a syringe to remove 10 cm^3 of solution from the large beaker. Run the solution onto a filter and collect the filtrate in a test tube.



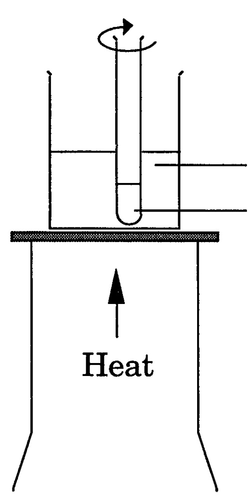


Look in the filter paper to see if any indigo has been lost from the denim. Filtering off some of the indigo makes it easier to see the result of the test for simple sugars.

2. Add 10 drops of Benedict's solution to the filtrate.

   Heat the filtrate in a bath of boiling water. A cloudy green deposit shows the presence of simple sugars.

   You could time how long it takes for the green deposit to appear, **but do not** wait longer than 5 minutes.



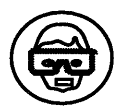
3. Repeat the test, collecting 10 cm^3 of solution from the large beaker after 20 minutes and after 30 minutes. Record all your results and observations.

SAG 5

SPECIAL EFFECTS

The special effect of extra wear on some parts of jeans (e.g. thighs and shins) can be created when garments are made. It used to be done by sand-blasting the jeans. Nowadays, a purple chemical called PM7 is sprayed onto the jeans before they are faded. PM7 removes some of the colour of the indigo dye. Using bleach could damage the denim. PM7 is short for potassium manganate(VII) solution.

Find out which concentration of PM7 gives the best results:

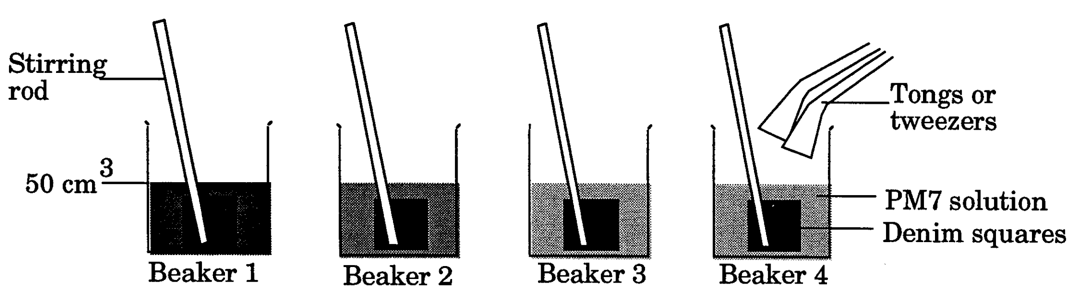
Wear eye protection 

Wear protective gloves 

1. Make up four solutions, shown in the table below, by mixing PM7 with different quantities of distilled water. In the empty column, write in which solutions are most and least concentrated.

Beaker	Volume of PM7 (cm^3)	Distilled water (cm^3)	Concentration
1	50	0	
2	25	25	
3	10	40	
4	2	48	

2. Add one square of de-sized denim to each beaker. Gently stir the contents.



3. After two minutes, use tongs to remove the squares. Do not handle the squares until after they have been washed.
4. Wash the squares in sodium thiosulphate solution to remove any left-over PM7. Now wash the squares in dilute detergent solution, rinse them in water, and allow them to dry.

   Compare the squares with wet untreated denim. Decide how the concentration of PM7 affects the rate of this reaction. Decide also which concentration is best for creating special effects.

PHOENIX - from ashes to flight in South Africa

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University of the Witwatersrand
Johannesburg, South Africa

October 1995

History

The Phoenix Programme was started in 1973 by the Mining Industry. Geoff Cox and Eileen Barret of the Mineral Industry Manpower Careers Unit at the Royal School of Mines, Imperial College, LondonUK, assisted in starting the Programme. The main business of the Programme was career recruitment and the activities focused on pupils in their last years of schooling. The activities of the Phoenix Programme became increasingly science-oriented over a 10 year period and began also to focus on the teacher rather than the pupil. The first workshops and case-studies that science teachers attended involved competitive group activity on the viability of starting a manganese mine. The teachers received resource material in abundance from these workshops. However the materials, being highly technical, were not in a format that could be used directly in the classroom. Teachers left the workshops with great enthusiasm but few got time to generate materials that they could use to teach their pupils.

In 1985, the Phoenix Programme in conjunction with the Chemistry Department at the University of the Witwatersrand began, for the first time, to develop resource materials, specifically for science teachers, that link concepts in the science syllabus to applications in the mining and mineral processing industry. To date, teacher resource packages on the mining and processing of copper, manganese, gold and chromium ores and coal have been developed. Resource packages have also been developed on methods of separation and containers and measurement.

It has taken ten years of work to develop these materials which are unique in South Africa. The materials aim to make vital technical information about mining and mineral processing accessible to the average science teacher in South Africa. In order to broaden the education base, the Phoenix Programme was transferred from the Chamber of Mines of South Africa to the Centre for Research and Development in Mathematics, Science and Technology Education (RADMASTE Centre) at the University of the Witwatersrand in January 1993. A new project has been initiated entitled *The development of a more relevant science curriculum*. The aim is to develop more relevant science teaching material which will promote meaningful learning. The materials that are developed will make explicit use of constructivist teaching strategies in conjunction with a science-technology-society approach.

The work of the last ten years has been recognised by education departments and workshops have been run on both an informal and formal basis, during the last seven years in many different provinces in South Africa. In recent times the work of the Phoenix Programme has been recognised internationally. Curriculum development groups at universities in other countries and certain international organisations have indicated interest in working with the RADMASTE Centre within South Africa as well as in other parts of the world.

The role of industry

The Phoenix Programme started as an industry initiative. As discussed, the aim was to stimulate interest in careers in the mining and mineral processing industry. The industry had a poor image related to the dirty and dangerous working environment located in uncongenial places. The Programme was focused on small numbers of people and hence did not have any significant effect on changing the poor image. In fact the image of the mining and mineral processing industry is still poor because in many respects the work is dirty and dangerous. The aim should not be to smoke screen the danger and dirt but to enable people to assess the risk of mining ventures where possible and also inform people of the benefits of adding value. Ignorance of the industry can only have negative consequences.

The formal relationship between the Phoenix Programme and industry has been predominantly through financial contributions. The Chamber of Mines of South Africa has funded approximately ninety percent of the total budget of the Phoenix Programme. The remaining ten percent of the Phoenix budget was funded by African Explosives and Chemicals Industries Limited, Envirotech (Pty.) Limited, Iscor Limited, Mintek and Rio Tinto South Africa Limited.

The donors attend a Board of Control meeting twice a year to monitor the work of the Programme. Donors debate and decide on the future of the Programme in conjunction with the programme manager.

Industry has cooperated on an informal basis with the Phoenix Programme in the last ten years. The developers of resource material have had to educate themselves about the industrial processes they were going to deal with in the resource package. The developers approached the relevant industries for the necessary technical literature on the process. Different mines supported the programme by donating rock samples (eg. the copper mineral - chalcopyrite, coal) while chemical plants supplied chemicals (eg. sodium ethyl xanthate for froth flotation) that were not readily available to the science teacher. Companies also provided video material that they had on the different plant processes and, where required, the opportunity for the processes to be photographed for 35mm-slides. Slides and videos assisted in bringing the industry into the classroom where it was not possible to experience the mining and mineral processing activities first hand.

Management of different factories agreed to show developers the industrial operations that were relevant to the packages being developed. Developers were taken underground to experience the mining operations. This experience was vital for the accurate representation of the work involved in mining and processing of the mineral being studied. Industry also reviewed the technical aspects of the material that was written, thus ensuring the accuracy of the material. During the training of teachers, industries also hosted visits for the participating teachers where possible. It was felt to be valuable for teachers to experience the world of work before presenting the materials to their students.

Teacher involvement in resource development

Science graduates with teaching experience were employed, on either a full or part-time basis, to research and design experiments and write the background and subject information, and activity worksheets for the resource packages. This involved reading literature on related topics, visiting relevant industrial sites and consulting with engineers, chemists and metallurgists for detailed understanding of the processes that were being presented in the resource packages.

The resource material was then presented to volunteer teachers for classroom trialling outside of formal teaching time. The teachers, in general, have come from a diversity of teaching environments from privileged to disadvantaged and urban to rural. Mostly the materials have been presented at half to one-day workshops where teachers were introduced to the contents and objectives and could try the activities for themselves. At the end of the workshop, teachers were given the opportunity to choose different sections that they would try out in their classrooms. The teachers were supplied with a questionnaire with which to describe their experience and to record the strengths and weaknesses of the materials. Responses from the teachers were used to improve the materials. Teachers who trialled the material in their schools and returned the evaluation questionnaires to the Phoenix Programme were acknowledged in the final version of the resource package.

Workshops were conducted at various regional and national science education gatherings. These were arranged by the local science teachers association, the South African Association of Teachers of Physical Science (SAATPS). Workshops at these gatherings were about two and a half hours in length. These workshops provided sufficient time for participants to be introduced to a new resource package. They also raised the level of awareness of those participating about strategies for making science more relevant to the learner. This lead to the more confident teachers implementing the materials at appropriate times in the year. For the less confident majority, the resource packages were too demanding and these teachers were unlikely to use them without a more extensive induction.

More extensive workshops were held in conjunction with various regional education departments e.g. Venda, Lebowa, Transvaal, and with the national Department of Education and Training. Teachers attended these workshops during formal teaching time. Workshops were one-day long and allowed a more detailed study of the resource materials. Implementation of the materials over a period of two to three weeks was also conducted in various regions in South Africa. Teachers were exposed to a far more rigorous inservice training programme and the attitudes and knowledge of students and teachers before and after the experience were assessed. Teacher and student feedback provided valuable information for future planning.

How the resources can be used

The resource packages were designed for use in two possible ways.

Firstly the package can be implemented at the standard nine (11th Grade) level of the current Physical Science syllabus. Ten hours of teaching time has been allocated to present an optional module on chemistry. However, regional education policy on optional modules varies. In some regions teachers have no options. In other regions science teachers can implement any science topic they deem relevant provided they consult with their Departmental officials. The resource packages developed by the Phoenix Programme are appropriate for use in this latter situation.

The second mode of utilisation is for teachers to enrich their teaching of specific scientific concepts in the core syllabus using appropriate student activity guides contained in the resource packages. Specific syllabus references, from standards five to ten (for students from 6 years old), for each of the activities in the resource packages are provided to assist the teacher in this regard.

How we developed resource materials

The first steps in the development of resource material was to identify objectives and set a timescale for the process. A search was then made for any teaching materials that might already exist on the topic of interest. These materials were not expected to be appropriate as they stood, but certainly could save much time and effort in avoiding duplicating work.

Whether or not teaching materials were available, there was a need to identify the relevant industries and sources of information. Literature searches were rarely used to obtain the relevant information. One must be selective when obtaining information as vast amounts of technical literature exist and one can easily become lost in a mass of information. The developer of the teacher material had to study and understand the technical information and this was often very difficult. When aspects were unclear, it was worthwhile contacting an industry expert. Representatives from industry were extremely helpful and supportive in this regard.

Once the developer had achieved a thorough understanding of the technical aspects of mining and metallurgical processes then small-scale activities were designed for use in the classroom to illustrate the large scale industrial processes. In many cases this was difficult and time consuming, and sometimes even impossible. Where industrial processes could not be represented on a small scale for use in the classroom, paper activities became the next best alternative. In these cases video or 35mm-slides could also be used to support the activity.

All materials that were prepared were reviewed and tried out by a small group of teachers. In most cases they were asked to conduct lessons and assess the value of the materials from the point of view of both pupils and teachers. The outcomes of their evaluation were used to modify the resource materials before any wider exposure was attempted.

Design and layout of the resource packages

The content of the resource packages

The resource packages developed over the past years have generally conformed to a similar pattern. The packages attempt to highlight the importance of a particular metal or mineral in the students everyday life, explore the geology of the mineral, the techniques used to extract the mineral from the ground and the effect thereof, the different processes used to add value to the mineral or metal and the socio-economic issues in the South African context.

The content of the resource package on coal is used to illustrate this point.

Chapter 1	Why coal?
Chapter 2	How do we find coal?
Chapter 3	How do we mine coal?
Chapter 4	How do we prepare coal for application?
Chapter 5	How do we get energy by burning coal?
Chapter 6	How do we get liquid fuels and other organic chemicals from coal?
Chapter 7	How is coal used to make fertilisers?
Chapter 8	How are plastics made from coal?
Chapter 9	How can we use coal to get metals from their ores?
Chapter 10	Where is coal mined and processed in South africa?

The original design of these resource packages was derived from scrutinising publications from various local and international science education initiatives. The Salters' Science Project and SATIS in the UK and the Science Education Project in South Africa are examples.

Each chapter in the resource package has six sections that will be discussed below. Some example pages from Chapter 4 of the coal package appear at the end of this chapter.

Introduction and subject information

The Introduction and Subject Information is designed to be used by the teacher. The language level is intended to be accessible to a second language user of English. The information in this section provides teachers with the necessary scientific and technical information in order that they may be an authority on the subject in the science classroom. This allows teachers to present the topics on the mining and processing of a particular mineral with more confidence.

Student activity guides and worksheets

Student Activity Guides are designed for the use of the students. The students are expected to do practical activities, in small groups, in the school laboratory or classroom. Where the situation does not allow group work, teacher demonstrations could be used. In the current situation in South African schools, it is expected that the latter mode of teaching will frequently be used.

The ***Activity Guides*** have the following sections:

Title, which is written in the form of a question.

Requirements list, where all equipment necessary for an activity is selected as far as possible from official catalogues of the various Education Departments. Any specialised material that is not on the catalogue is available from the Phoenix Programme (e.g. powdered ore samples).

Method, which describes the procedure for a particular activity. In general, all activities are designed to be completed in a forty minute period. Certain activities do require more time. The activities are designed to represent an industrial process as closely as possible. Actual minerals are used in as many of the activities as possible.

Observations, provides space for the student to record the experimental observations in a table format or under the guidance of set questions.

Conclusions, comprise a set of questions that guide the student to providing an answer to the question posed in the title of the activity.

Student Worksheets, provide for activities that do not involve laboratory work. These activities involve group and individual work with reference material. The activities involve reading, comprehension, data manipulation, map reading, analysis, evaluation, synthesis and communication skills. These activities may be less stimulating for the average learner and require extra initiative from the teacher to present the material successfully. However they may link with geography classes, etc. and help break some subject compartmentalisation.

Tables and diagrams

Tables are used in the teaching package to assist the teacher in presenting data to the class in an organised manner. When appropriate, information tables can be given to the students when completing Student Worksheets.

Diagrams are included in each chapter for the purpose of providing pictorial information on the processes that are of relevance to that particular chapter. The diagrams convey, in a limited way, the scale of the industrial processes that are being discussed. Where appropriate, maps are also provided in this section.

Teachers notes

The Teachers Notes are completed Student Activity Guides and Worksheets with the expected observations and 'correct answers' provided. The purpose of the Teachers Notes is to give the teacher the confidence to try the material. This section also provides the teacher with additional information about the activities such as how to make experiments work well, safety tips and alternative methods that can be tried.

Evaluation and evaluation tools

Teacher evaluation

The teacher evaluation of the resource packages was based on assessing the value of the resource to the teachers. A questionnaire was designed which explored whether, in the opinion of the teacher, each section of the resource package fulfilled its intended purpose.

The questionnaire enquired whether the Introduction and Subject Information provided a good understanding of the content of each chapter, allowing teachers to become an authority on the subject being presented. Similar information was obtained on the Teachers' Notes.

Teachers were asked to describe the teaching strategies that they used and to provide information on the sequence of events that took place, how the topic was introduced, which activities were used and how the topic was concluded. The context in which materials were presented to the students was also solicited.

Questions on the Student Activity Guides and Worksheets provided information on the method of presentation used, the usefulness of the activity guides and worksheets, parts of the experiment that did not work or that could not be done and any difficulties that were experienced in obtaining the necessary chemicals or equipment.

The teachers were asked to comment on the value a chapter would have for their students in relation to knowledge, laboratory skills and attitudes.

From one evaluation, a teacher felt that the pupils really enjoyed the experience. To quote:

> *"They enjoyed the experience and were more positive than any other time this year. It was a pleasure to teach the same pupils who usually are completely switched off something that showed them as intelligent, capable and inquiring young scientists."*

Student evaluation

The student evaluation attempted to ascertain what the students had learned from the activities they had experienced, whether the activities were enjoyable or boring and whether they would like to do more of a similar kind in the future. Students were also asked to identify parts of the worksheets that were unclear or confusing.

Outcomes of student evaluation :
Example: the resource package on coal

The evaluation indicated that students did enjoy the activities. One reason for the positive response was that the students enjoyed doing experiments themselves which did not happen very often in their normal learning routine. To quote:

> *"Yes, I did. Because the experiments were done by us and not the teacher."*

A second reason was that the activities exposed them to new information that was not in the normal syllabus. A response:

" *Yes. It was very interesting because it taught me things that I did not know.* "

Students felt that they became bored because of three factors:

- they had to wait for a reaction to take place, quoting:

"*Yes.Because you had to wait so long for the coal to burn, before you could test it.*"

- worksheets were boring compared with experiments. One student said:

"*Sometimes the chapter was boring when we worked on the worksheets and I was bored.*"

- experiments that did not work easily. To quote:

"*Yes, those which were unsuccessful. We had to repeat again and again it was unsuccessful.*"

Another student felt the opposite about experiments that did not work easily. This pupil said:

"*The best part was when we could not succeed with the second experiment and everyone took a chance.*"

The negative responses about boredom are indicative of immaturity. The age range of the students was from thirteen to sixteen. One has to be careful not to kill enthusiasm for science by presenting demanding activities too early in the students learning process. A balance needs to be achieved as far as enjoyment and discipline are concerned. Only the teachers can achieve this balance, as they know their students and can present different activities to suit different groups.

Many students who were confused identified their confusion as due to not being able to enter data into tables and not understanding the language. Two quotes indicating this:

"*The Table in No. 1. I didn't know what was meant by NEW SUBSTANCE or much about filling it out.*"

"*I didn't understand some of the questions - please write in English.*"

There were areas of confusion in one of the tables which was poorly designed. These weaknesses were rectified in the first edition of this resource package. The language level was also too difficult for many students and this will also have to be revised.

All the students involved in the implementation of the resource material felt that they had learned something that was new and/or worthwhile and wanted to be involved in more of this type of learning activity.

Conclusion

Through much of the history of the Phoenix Programme, the development of the materials has been motivated by the belief that:

i) many students are not stimulated by the abstract beauty of chemical principles, concepts and models alone

ii) many students learn chemistry like they used to learn Latin - as a fundamentally incomprehensible and purposeless activity

iii) even students who can comprehend the abstract concepts of chemistry, in many cases are unable to identify their relevance with respect to their daily lives, technological activity, etc.

All three points lead to the same consequence of a lack of interest in chemistry and a lack of understanding of how it fits all-pervasively into their lives.

The development has in fact been underpinned by a belief that learning about one's environment, getting a feeling that indeed a pattern of abstract concepts may perhaps make sense of it all, may be stimulating. Our experiences strongly suggest this is so.

However, we also know from experience that a couple of lessons on coal won't necessarily change student's attitudes to science. They will probably be positive memories, but little more. In other words, substantial impact on attitudes is likely to be achieved only by adopting a continuing strategy of opening windows onto the real world outside. This is why our group is now embarking on the project mentioned earlier: *The development of a more relevant science curriculum.*

We are continuing to work with teachers in our area. Most of the teachers lack the time and resources to initiate anything substantial on their own but enjoy participation in a group where independent funding maintains a small full time core team.

Our core team is now located at a university and this is probably advantageous although not essential. For a university committed to serving the community it is an appropriate and rewarding activity. We trust that the originators of the Phoenix Programme more than 20 years ago, will be pleased at the way their old bird is now taking to flight.

Acknowledgements

We acknowledge with gratitude the participation of many teachers and students in, and the financial support of donors for, the Phoenix Programme during its long history. We also particularly wish to acknowledge the very special contributions of Eileen Barrett, Marie Brand, Albert Chauke, Geoff Cox, Mark Demmer, Sue Marsden and Robbie Robinson.

4.1 INTRODUCTION AND SUBJECT INFORMATION

Coal preparation is the process of upgrading the quality of the coal that has been mined to meet the customer's needs. Beneficiation is the most common term used in industry to describe this upgrading process. Coal cleaning and coal washing are similar terms used to describe the process of coal preparation.

Coal beneficiation is necessary for two main reasons.

1. The most important reason for coal cleaning is the fact that various applications of coal require specific qualities of coal (See Tables and Diagrams 2.3 [1]). The majority of South African coal deposits have a relatively high ash content and an inconsistent quality (Chapter 2). Without coal beneficiation, the coal mining industry would not be able to supply a product that would meet the customer's specifications. This would result in the closure of large sections of the coal mining industry.

2. When coal is mined, by both underground and opencast methods (Chapter 3), small bits of rock at the boundaries of the coal seam are also broken. This waste material collects on the floor of the mine amongst the fragmented coal. Varying quantities of rock are trapped within the coal seam due to various conditions during the slow formation of the seam (e.g. rock from molten magma that flowed into lines of weakness in the coal seam and then cooled and solidified). This rock increases the amount of dirt in the mined coal. Foreign objects like pieces of steel from mining machinery and wood also contaminate the coal.

The mined coal and waste material is loaded by sophisticated machinery that loads large amounts of material quickly but does not select the type of material that it loads. Hence both the coal and the waste material is transported out of the mine.

The inclusion of waste rock and pieces of metal in the mined coal lowers the calorific value of the coal and results in an inferior quality of coal. Furthermore, metal objects and waste rock are very abrasive. The presence of such material could damage the customer's equipment and increase the maintenance costs of the customer's plant (e.g. a coal grinding mill at a power station).

Coal Preparation Techniques.

Metal objects that are made of iron are removed from the coal with the use of powerful magnets. The removal of metal objects occurs as the coal emerges from the mine.

Coal preparation processes remove waste rock and coal with a high ash content to meet the requirements of the customer. All the techniques use the physical property of relative density to separate the required coal fractions. Waste rock and coal with a high ash content have high densities relative to coals that have a low ash content. Using density differences between that of the waste material and the high quality coal, an efficient separation can be achieved. The waste materials sink while the coal with the low ash content floats.

The beneficiation processes are slightly more complex than is described in the last paragraph. South African coals have ash contents that vary within small sections of a coal deposit. Hence, there is a range of relative densities in any coal deposit. This makes the separation more complicated and less efficient as coal pieces having densities close to the density of the separating medium will separate out at a slower rate than the high quality coal and waste material.

4.1 INTRODUCTION AND SUBJECT INFORMATION cont.

The coal is in some cases broken into smaller particles. This releases some of the mineral matter that is trapped in the coal and allows for further beneficiation to take place.

The three basic methods that use the property of relative densities are Jigging, Dense Medium Separation and Dense Medium Cyclones.

JIGGING (The Jig Washer)

Jigging is the oldest method of cleaning coal and has been used since 1848. This method has become out-dated and is not used on many South African coal mines at present. The first jigging operations consisted of a movable basket that was operated by hand. Coal was placed in the basket. The basket was moved up and down repeatedly, in a large container of water. The particles of low relative density rose to the top of the coal pile while the coal with a high relative density sank to the bottom of the pile, resulting in a separation.

Later developments led to a jigging apparatus with a stationary basket and repeated pulses of moving water in both the upward and downward directions (See Tables and Diagrams 4.3[1]).

Jigging works on the principle that a rising current of water will raise particles of lower relative density more than particles of higher relative density, of the same shape and size. Particles of lower relative density will have a smaller sinking velocity than particles of higher relative density. This means that a slower upward water current is required to cancel the downward velocity of the particles of lower relative density compared to that necessary to oppose the sinking velocity of the particles of higher relative density. Ideally, by applying an upward current with a strength between the magnitudes of the downward velocities of the particles of low and high relative densities, one can force the particles of low relative densities to rise while the particles of high relative densities are still sinking, thus obtaining a separation.

In brief, upward currents would force particles of lower relative density upwards faster than the particles of higher relative density, thus producing a separation. In a similar fashion, downward currents would force particles of higher relative density to sink faster than the particles of lower relative density, thus also resulting in a separation.

Once a suitable separation has been obtained, the high quality, low density, coal can be removed from the jig and despatched to the customer.

DENSE MEDIUM SEPARATION

Dense Medium Separation was introduced because both the waste material and the high quality, low density, coal are more dense than water. This means that both materials sink in water.

A dense medium (liquid or solution) is required that has a relative density greater than the high quality, low density, coal and less than the waste material of high density. This would ensure that the high quality material floated while the waste material sank, producing an efficient separation. Liquids like carbon tetrachloride (CCl_4), bromoform ($CHBr_3$) and an aqueous solution of calcium chloride ($CaCl_2$) were used in laboratories to give excellent separations.

The only problem with these liquids and solutions is that they are extremely expensive and large scale beneficiation operations that use these substances are not cost effective.

4.1 INTRODUCTION AND SUBJECT INFORMATION cont.

This problem was overcome by using a suspension of magnetite (Fe_3O_4) - in a finely divided state - in water to separate the material of low and high relative densities. The particles of magnetite increase the average density of the suspension. The relative density of the suspension is determined by the proportions of magnetite and water. A suspension of this type is called a 'Dense Medium'.

Example: If 1 cm^3 of finely divided magnetite with a relative density (R.D.) of 5.0 is added to 10cm^3 of water then the relative density of the suspension is calculated as follows.

MASS OF 10cm^3 OF WATER (R.D. = 1) = 10cm^3 x 1g cm^{-3} = 10g

MASS OF 1cm^3 OF MAGNETITE (R.D. = 5) = 1cm^3 x 5 cm^{-3} = 5g

*VOLUME OF SUSPENSION = 1 cm^3 + 10 cm^3 = 11 cm^3

MASS OF SUSPENSION = 10g + 5g = 15g

$$\text{DENSITY OF SUSPENSION} = \frac{\text{MASS OF SUSPENSION}}{\text{VOLUME OF SUSPENSION}} = \frac{15\text{g}}{11\text{ cm}^3} = 1.36\text{g cm}^{-3}$$

$$\text{RELATIVE DENSITY OF SUSPENSION} = \frac{\text{DENSITY OF SUSPENSION}}{\text{DENSITY OF WATER}}$$

$$= 1.36 \text{ g cm}^{-3} / 1 \text{ g cm}^{-3} = 1.36$$

* In practice, the volume of the suspension would be less than 11 cm^3 because 1 cm^3 of powdered magnetite includes the air that exists between the magnetite particles.

Magnetite and sand are used extensively in the South African coal mining industry for dense medium separations.

Many bath designs are available for large scale dense medium separation. There are two main designs in common use.

1. Deep baths use a large volume of the dense medium but have the advantage of separating three fractions of material, i.e. waste material, medium ash coal and low ash coal (See Tables and Diagrams 4.3[2]).

2. Shallow baths use a smaller volume of dense medium than the deep bath, but can only separate two fractions of material, i.e. waste material (mixed together with medium ash coal) and low ash coal (see Tables and Diagrams 4.3[3]).

Both types of baths are used to separate coal with a particle size ranging from 125mm to 50mm. Particles of the size ranging from 12mm to 0.5mm will not be separated successfully because the speed of sinking and floating would be too small relative to the flow rate of the medium (i.e. the residence time in the bath is too short).

4.2(a) STUDENT ACTIVITY GUIDE

CAN YOU SEPARATE PARTICLES OF COAL WITH DIFFERENT ASH CONTENTS USING THE PROPERTY OF RELATIVE DENSITIES?

Requirements:

1 x 100cm^3 measuring cylinder
1 x 200cm^3 beaker
1 x mass balance
1 x spatula
1 x packet calcium chloride ($CaCl_2$)
1 x packet of coal pieces

Method:

1. Weigh out approximately 47g of calcium chloride.

2 Transfer the calcium chloride into the measuring cylinder.

3. Dissolve the calcium chloride in 50cm^3 of water. Be careful as this is an exothermic process!

4. Cool the solution under cold tap water and make the volume of the solution up to 100cm^3.

5. Ensure that the coal pieces are smaller than half the diameter of the measuring cylinder. Large pieces can be crushed with a hammer.

6. Drop the coal into the calcium chloride solution. Cover the opening of the measuring cylinder with the palm of your hand and shake the measuring cylinder a few times.

7. Put the measuring cylinder on the table and observe what happens to the coal. Record your observations below.

8. Remove the coal pieces from the measuring cylinder, keeping the coal that floated separate from the coal that sank. Keep the calcium chloride solution for the next class.

9. Rinse and dry the coal pieces that you have separated. Observe the appearance of the surface of the coal in each group of coal pieces and answer the questions below.

4.2(a) STUDENT ACTIVITY GUIDE **cont.**

Observations:

1. What happened to the coal in the calcium chloride solution when you stopped shaking the measuring cylinder?

____

____

2. What did you notice about the appearance of the surface of the coal in the two groups?

____

____

____

Conclusion:

1. Have you successfully separated particles of coal with different ash contents using the property of relative densities? Explain.

____

____

____

____

2. If you can identify good quality coal from poor quality coal by the coal's appearence, why not hand sort the coal?

____

____

NOTE: You might like to do an ash content analysis on the two coal samples (see Chapter 2, 2.2[d]). This will provide experimental evidence of the success or failure of your separation.

Application:

1. Using the information below calculate the cost of processing 7 200 000 tonnes of coal in a Wemco Drum (See Tables and Diagrams 4.4[3]). Use a calcium chloride solution as a separating medium. The Wemco Drum requires 900 000 litres of separating medium to process 400 tonnes of coal per hour. The 900 000 litres of medium is recycled and reused for every 400 tonnes of coal. However about two litres of medium is lost per tonne of coal processed due to the fact that some of the medium remains on the surface of the coal.

SUBSTANCE	COST
CALCIUM CHLORIDE*	R35,00 PER KILOGRAM
CARBON TETRACHLORIDE	R10,00 PER LITRE

* 0.5kg of calcium chloride are required per litre of water.

4.2(a) STUDENT ACTIVITY GUIDE **cont.**

1.1 How many litres of medium will be lost when processing 7 200 000 tonnes of coal?

1.2 How many kilograms of calcium chloride are used in 14 400 000 litres of water?

1.3 What is the cost of the calcium chloride used?

2. Use the information given below to determine what effect these costs would have on the end price of the coal.

2.1 After the coal processing operation, 5 400 000 tonnes of high quality coal are available for sale. If this coal is sold at R40 per tonne, what would be the income from this sale? Assume 25% of the original 7 200 000 tonnes was discarded as low quality coal.

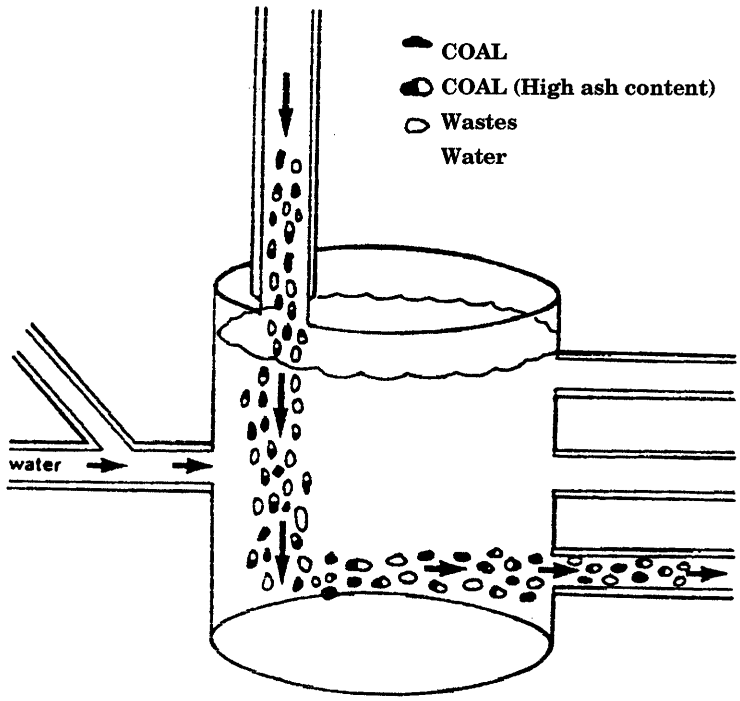
2.2 What is the net profit after accounting for the cost of the calcium chloride?

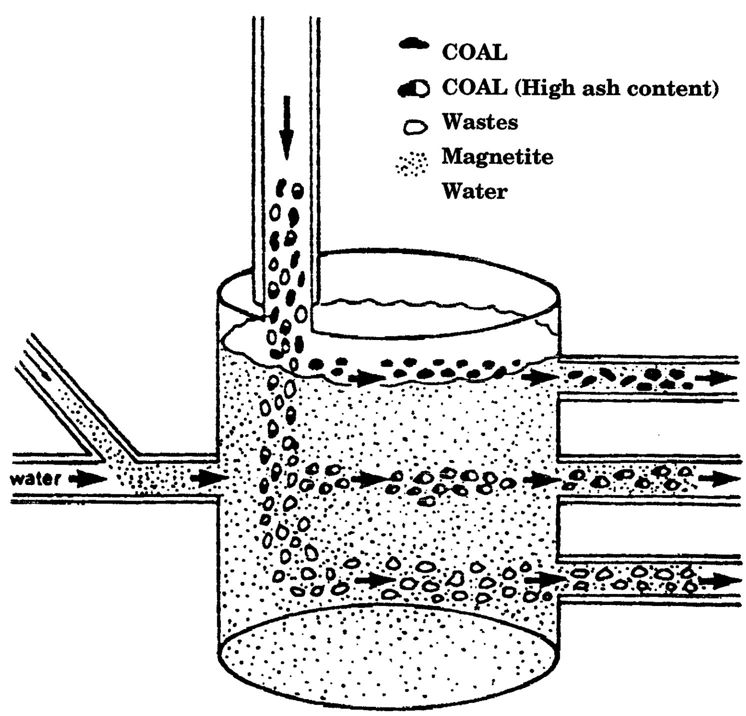
2.3 At what price would you have to sell your coal to make a 36 million rand profit? Comment.

3. Suggest a solution to this problem.

4.3(2) **TABLES AND DIAGRAMS**

DENSE MEDIUM SEPARATION





A USA model of industry-academic partnership in the dense urban area of Orange County, California

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December 1995

Introduction and brief history

Introduction

Established in 1982 at the University of California, Irvine (UCI), California, the UCI *Science Education Program* is a suite of programs offered by a partnership between a major research university, private industry, and local education authorities in an urban area with the goal of providing mechanisms for continuous modernisation of precollege science education. The enterprise is conducted by two faculty members of the Chemistry Department, but encompasses all fields of science and engineering. A key component of the UCI model is the involvement of UCI science faculty members, primary and secondary school teachers, and industrial representatives as co-instructors in the *UCI Summer Science Institute for Teachers* and other year-round science education programs for teachers of primary and secondary school students. Programs are designed to address science content, relation of science education to industrial and research uses of science and technology, pedagogy of science learning and instruction, and equity in reaching all students in a multi-cultural, multi-ethnic society. The university-based institutes and related activities are guided by a *Science Education Advisory Board* meeting regularly to provide and foster leadership. Membership is listed in appendix A.

A complete compilation of programs operated as part of UCI's *Science Education Programs* is provided in appendix B. Some additional information is available through our World Wide Web page accessible at http://www-sci.lib.uci.edu/SEP/SEP2.html

Background: University of California, Irvine (UCI) and Orange County, California

Orange County, California, home of the original Disneyland, is a dense urban area of approximately three million inhabitants, of which about 0.5 million are school age children. The school system of the county is divided into 27 separate Local Education Authorities (School Districts) of widely differing sizes - from small single elementary school districts or single high school districts, to large unified districts with many elementary, middle, and secondary schools. The University of California, Irvine (UCI) is a branch of the nine campus multiversity system of the University of California founded to serve the research and doctoral training needs for the State of California and is located in the centre of the county. Also serving the tertiary education needs of the county are:

- one campus of the state-wide California State University (California State University, Fullerton, CSUF)
- one private University (Chapman University)
- seven two-year community colleges
- several small religious foundation colleges.

UCI, founded in 1965, has approximately 13 000 undergraduates and 3000 graduate students in a broad array of departmental major programs. Unlike many other US universities, UCI departments are organised into schools, each headed by a Dean. The School of Physical Sciences houses a total faculty of 90 members in the Departments of Chemistry, Earth Systems Science, Mathematics and Physics. The School of Biological Sciences and the School of Engineering are each separate larger organisations with many departments.

Orange County is a relatively wealthy area of the State of California, with a concentration of financial company headquarters and modern light industries such as pharmaceutical, biotechnology, aerospace, computers, electronics, and entertainment. However, also located within the county are several older, low income, areas. In general, expectations in the community for good quality education are high, but the county is also home to many individuals most anxious to keep taxes low and to resist government organisation and regulations.

Science Education Experience in the 1970s in Southern California

In the late 1970s, faculty members in the chemistry department, and others, expressed concerns about the general preparation of science students in the schools and the level of understanding of science shown by students entering the university.

Two faculty members in chemistry undertook to pursue building better bridges between the university and the schools from which the students came. Information about university performance (scores on examinations and laboratory work) in first-year chemistry of former students was shared with their high school teachers in after-school meetings.

It was the consensus that a major problem was the lack of any or appropriate science education in elementary and middle schools. At the same time, industrial employers were expressing concerns about the lack of scientifically trained employees entering all levels of employment.

Particularly absent was any attempt to relate science studies in school classrooms with science and technology occurring in the world outside the school, particularly in business and industry, but also in research laboratories at the universities. Twenty years later, these problems have not been fully overcome, due, in part, to societal changes that have made working conditions in the schools (class sizes, limited English-speaking abilities of students, budgets for supplies, administrative constraints) more difficult.

Historical Development of the Science Education Programs in the School of Physical Sciences.

In the early 1980s one of the local unified school districts (Irvine) decided to address this issue in part by selecting thirteen science specialist teachers to teach all their 4th through 6th grade classes (10-12 year olds). UCI was approached to provide inservice education for these teachers in the summer preceding their first classroom work. Thus began the *UCI Summer Science Institute*, the first project of this organisation.

Clearly the area that these teachers felt most uncomfortable with was the entire realm of physical sciences, including chemistry. If any, their background was in life science curriculum and children's health issues. The success of the first year led Mare Taagepera and George Miller to decide to offer a summer course in physical sciences for elementary and middle school teachers from anywhere in the county entitled *Modern Unified Science.* Titles of courses offered are listed in appendix C.

In the United States, professional development for accredited teachers is rarely mandatory, and teachers historically have viewed themselves as underpaid and undervalued by society. Success of the program was seen as highly dependent on being able to make the program cost-free to teachers. In addition, many teachers routinely took alternative employment in the three-month summer break to supplement their incomes. Thus, it was important that some replacement income in the form of stipends be offered to attract teachers away from such employment into the professional development courses.

Some financial support for such offerings was obtained from the University, both from the central Academic Affairs office, and individual science departments. School districts other than Irvine were not eager to pay for their teachers to attend. Thus an approach was made to local industry to support the programs. Several local companies, including those in international defence contracting, pharmaceuticals, and oil and gas industry construction agreed to sponsor individual teachers for $1500 each to cover stipends and course fees. *The UCI Summer Science Institute* was initiated fully in 1982 with 46 teachers sponsored by 12 local corporations. In 1983, 100 teachers were included and sponsorship was obtained from 25 corporations. In the same year, operation of several programs during the remainder of the year was begun.

It was clear that the sponsors would need to provide guidance and continuing support for the expanding programs. A *Science Education Advisory Board* was formed consisting of:

- local industrial personnel managers and scientists, often research directors of their organisations
- UCI faculty members from biology, chemistry, physics, engineering and mathematics
- school teachers
- community education representatives.

This group gave impetus to expansion of programs both within and beyond the Summer Institute itself.

One corporation, ARCO, agreed temporarily to provide additional support through its industrial foundation. This provided support for staffing to operate the programs and organise the industrial support and linkages. In addition, state and federal grants were sought and obtained for specific program development within the organisation.

A three year federal government grant was obtained from the National Science Foundation in 1985 specifically to address the needs of 'cross-over' teachers, that is, those assigned to teach science but who have little science education themselves. In 1990, the State of California began a program to offer base funding to the university for provision of professional development programs for teachers and UCI became a regional site for this *California Science Project*[1]. In 1994, a five year Science, Technology and Society grant was obtained from the National Science Foundation to support an extensive program of industry-education collaboration in science education.

Organisation and Staffing

The Science Education Programs (SEP) office is directed by two faculty members of the Chemistry Department at UCI. Both have normal full-time duties in teaching chemistry courses to chemistry, engineering and biology undergraduate students. A full-time Program Co-ordinator is responsible for all programs, fiscal management and relations with school districts and teachers. A second full-time individual is responsible for industrial relations, program promotion and general fund raising. Individual programs have part-time co-ordinators salaried from funds raised to support those specific needs. The office makes good use of the availability of undergraduate science and engineering students as part-time employees to enable high quality, low cost, general and specific service to the programs.

Links with Industry

Our links with business and industry partners have matured as our programs have evolved and grown. Throughout, the *Science Education Advisory Board (SEAB)* has been a key component in steering the operations. The *SEAB* operates through regular monthly breakfast meetings during the academic year, and through the formation of subcommittees to develop and guide specific projects.

At the start, the primary focus, other than general advice, was in the area of funding support. *SEAB* members undertook to use their own network of contacts to raise funds using the "support a science teacher for $1500" slogan. This was a very successful approach through the early 1980's, and a budget of around $60 - 80,000 per annum was accumulated in this way.

Beyond that time, other tax supported avenues of support for teacher professional development were introduced or strengthened at the state (introduction of the California Science Project) and federal (Eisenhower Education Act funds for science and mathematics education improvement) levels. This, together with a slump in the local aerospace business activity as the US defence budgets were reduced, and a slump in oil industry profits and local investment in research led to new emphases in the late 1980's to the present time.

Members of the *SEAB* and personnel from the companies they represent have taken an increasingly active role in curriculum design and instruction for the teacher inservice courses in the Summer Institute. Starting in 1994, as part of the OCSTS Network (OCSTSN) described below, they also began to act as mentors to individual teachers to provide connections for those teachers into the "real world" of industry and access to additional resources for the classroom. Several of the individual programs involving industry partners are described in more detail below.

Modern Technology Program

In 1983 a 'Special Topics' course was initiated in the fledgling Summer Science Institute[2, 3] program to connect secondary school courses to the world of research and industrial technology:

Week 1 Genetic engineering

Week 2 Modern technology: covered industrial site visits in

- electronic navigational systems
- pharmaceuticals and design strategies for new drugs
- satellite communications
- offshore oil piping and refinery construction
- petrochemicals research and development

Week 3: Atmospheric chemistry

In 1986, a sub-committee of the *SEAB* was formed to expand the Modern Technology idea to a full three-week course. A UCI faculty member co-ordinated the program together with a high school teacher in which industrial scientists and engineers provided week-long sessions regarding the science and technological applications of a portion of their industrial businesses. Different topical areas are selected each year. A Modern Technology Course Outline is described in appendix D.

The Orange County Science, Technology, and Society Network (OCSTSN)

Enthusiastic about the successes in the Institute Course, and looking for new avenues for partnership, a sub-committee worked to submit a major grant application in 1993 to support development of all infrastructure in Orange County for the continuous infusion of science, technology and society issues into the secondary curriculum. This was funded in 1994 by the National Science Foundation.

The Orange County Science, Technology, and Society Network (OCSTSN) blends the expertise of educators with the scientific, technical and management skills of industry for the purpose of providing a modern technology perspective designed to capture the interest and imagination of students in their most formative years.

By 1997, over one hundred mentors/collaborations from industry will have been working in a partnership designing replacement curriculum units addressing ten critical technologies, and instructing their colleagues in how to implement these materials. The topics include biotechnology, space science, electrical energy, new construction materials, water utilisation, medical technology, technology of advanced uses of oil, environmental technology, and communications technology. In each area it is intended that societal issues, primarily ethics, and benefit and risk analysis be included.

A broad objective of this project is to open and form permanent communication lines between the various segments in the educational system and the industrial community to provide for a systematic and ongoing infusion of science, technology, and society (STS) issues into the curriculum in an effort to provide an enriched and more meaningful pre-college science curriculum for all students.

The 1995 OCSTSN encompassed 42 Teacher Fellows, each assigned to at least one mentor scientist or engineer from 50 Orange County industries. These Fellows and many of their industry partners attend regular monthly meetings at UCI and have attended a special three-week Summer Institute. In the Institute, they learn about the curriculum, make field trips to the industry sites involved in the curriculum topics, and rework the curriculum units after field testing in the schools. Industry mentors are asked to make at least one visit each year to the science classrooms, and many are actively becoming engaged in the instructional process by helping to make the curriculum materials "come alive" for students.

A novel and important feature of this project is the inclusion of secondary school students as full working members of the curriculum unit development teams. A few of these students have even been part of the instructional team for the Summer Institute presentations of the curriculum unit on which they had worked. In California teacher inservice programs, a popular slogan has been to encourage teachers teaching teachers. In this project a new slogan is born: students teaching teachers.

Biotechnology Program

The Biotechnology Program is an example of a component that directly works with secondary students as well as with secondary teachers. Guided by a sub-committee of the SEAB, two main offerings have been created.

In the first, teachers are trained in a series of new curriculum workshops that encompass modern biotechnology laboratory activity teaching units suitable for high school students (grades 7-12, ages 13 - 18). Some of these were pre-packaged units from the Cold Springs Harbor Program, others are developed by teachers in collaboration with university and industry biologists. The first group of biotechnology fellows were responsible for creating workshops for their colleagues in the schools.

The second program offered in biotechnology was a series of public lectures addressed to high school biology students, initiated to provide an opportunity for students, teachers, and members of the general public to update their understanding of current issues in science. The 1995 series presented topics in the biotechnology/biomedical field. Teachers were encouraged to bring entire classes of students. Attendance was 200-300 each session. Topics included descriptions of research and development being done at the Beckman Laser Surgery Center, the Cancer Research Institute, the Center for Neurobiology of Learning and Memory, and the Brain Imaging Center.

Future of Science Conference

Future of Science Conference is organised as a once a year opportunity for local scientists, and teachers of science (primary, secondary, and tertiary) to reflect on the recent and future developments in science research and science education. The format involves a keynote address followed by a panel discussion. The panel is made up of individuals representing differing viewpoints on the conference theme. The afternoon sessions are devoted to practical workshops developed and presented by teachers or industry scientists. Time is also allowed for networking during lunch and at a reception following the conference. Attendance of 100-150 is usual.

Topics for the keynote address have included the following:

The Hole in the Ozone Over Antarctica
Windows on the Brain
The Influence of Brain Development on Learning
Darwin and the Bible
Teaching Evolution
Evolution of the Human Influenza Virus
Aspects of Behavioural and Social Science Measurements
What is a Neutrino?
Stress Hormones and Memory
Medicinal Chemistry of Herbs
The Greenhouse Effect and You
Science Education
The Future Depends on Us

The 1994 program on the theme of *The Future of Science Education: Partnerships for the Third Millennium* is included in appendix E.

Awards and Honors Programs

Modern American society respects what is highly valued. As the future of the nation depends more and more on scientific and technological innovations, it is important to value those who educate the technologists, scientists, and informed citizens of the future. To this end, the UCI *Science Education Advisory Board* through its industry sponsorship makes several awards each year. Since school budgets in California for supplies for science teaching are generally very small, modest monetary awards to departments for purchasing supplies are highly valued.

- Outstanding High School Science Teachers Awards in Chemistry, Physics & Biology

Three secondary school science teachers have been honored annually since 1983. The teachers are nominated by former students who currently attend UCI. They are honored at a dinner where their former students are given the opportunity to recognise the teachers' contributions to their lives. Each teacher and his or her school science department is recognised with a plaque and a payment check. These are jointly presented by the chairs of the respective UCI science departments and the industry leadership of the SEAB. The SEAB funds the dinner to which school administrators, and school colleagues and families of the teachers are invited.

- Orange County Science Fair Awards For Secondary School Excellence

This science fair is county-wide, and has its own industry-sponsored Board. Many members of the UCI *SEAB* are also active in support of the fair, through direct contributions towards expenses, and as judges of the exhibits. All entrants must have previously competed at their school and/or school district science fairs before entering the county event. The UCI SEAB awards are given to the junior and senior high school that receives the largest total of individual student awards at the fair. The awards are thus a recognition of a joint effort on behalf of all the teachers in the science department and a monetary award is given to the department to supplement their supply budget in addition to entry of the school name on a perpetual plaque.

- Award For Outstanding Contributions To Science Education

Established in 1992, this award is made each year to individuals who have made outstanding contributions to furthering science education in the secondary school system and at the university level. To date, this has been awarded to five teachers of science, two members of the National Academy of Sciences and Engineering, two chairs of the UCI Science Education Advisory Board, the UCI Vice Chancellor for Research, the Co-ordinator of the UCI Biotechnology Project, and the Director of the UCI Science Education Programs. These individuals have all excelled in their promotion of, and dedication to, science education locally and statewide.

Budgets

As indicated earlier, the budgetary support mixture has changed over the years. It has been important for survival of the overall enterprise that no single source of funds be relied upon. Recent events in the US regarding formerly stable federal and state support for education have reinforced this notion.

Within the program, industry contributions have averaged $60,000 to $80,000 per annum. However this has changed from the beginning when many companies donated small amounts, to support mostly from a few larger corporations. University direct funding support has dwindled to almost nothing as UC budgets have been tightened. Modest space is provided at no cost by the university, but all support costs (telephone, copying, etc.) are charged to the program.

Base funding from the State of California has been steady for five years at $135,000 for the California Science Project segment. Grant funding from NSF is about $350,000 per year for the OCSTSN project. Course fees are paid for some teachers through school district monies obtained from the federal Eisenhower fund supporting teacher professional development in mathematics and science. Most of these funds are expended in direct teacher stipends and instructional staff support. Appendix F displays how the various portions of fiscal support has changed over the years from 1982 - 1995.

Project Proliferation

UCISEP has instituted a three-year internship program for colleges and universities interested in starting their own science institutes for teachers according to the UCI model. The project, named *Project START* is sponsored through the Far West Regional Consortium for Mathematics and Science Education based at Far West Laboratory (US Department of Education).

The first *Project START* Leadership Conference was in August of 1993. Four leadership teams (teachers, professors and administrators) from four sites (California State Universities (CSU), Hayward, Chico and Sacramento, together with the College of the Desert) attended. CSU San Bernardino joined in 1994.

Special courses were developed for participants with particular attention given to:

- existing programs and materials
- effective inservice mechanisms
- private/public partnerships
- fund-raising
- nuts and bolts of good programs

In 1994 all sites were in various stages of developing their own teacher enhancement programs and in 1995 are submitting their plans for sustainability, including formation of Advisory Boards, and seeking local industry partners.

Evaluation

Evaluation of the programs is ongoing in a variety of ways. The Science Education Advisory Board reviews most programs at each monthly meeting, and devotes one meeting specifically to a review of the written annual report and budget projections for the year, making suggestions for changes and improvements for the subsequent year. A small executive group of the Advisory Board also evaluates the operation of the Board each year, and makes suggestions for changes in membership, assignments, and operations.

Within each segment of the program, the co-ordinators arrange for overall program evaluation usually by means of pre- and post- Institute participant surveys. Many of these are condensed for inclusion in the annual report to the Advisory Board. Generally teachers have rated all programs as "highly successful and informative" in the 4-5 range on a 1-5 scale.

A vital part of all programs has been the Daily Evaluation. Each day, in every program, each participant including teachers and students (where applicable) completes a daily form rating each of the day's activities, and providing written comments on questions such as "What I found most useful in today's program", "What most needed change in today's program?". At the end of every day, the instructional and co-ordinating team reviews these surveys and makes important adjustments for the following day.

The large grant-funded programs include budgets for external evaluation by professional evaluators. In the case of the OCSTSN project this is resulting in intense efforts to examine several important facets of the program. For example, industrial scientists in the project and teachers are keeping logs of the time and nature of their interactions. Classroom visits are being conducted to assess the impact of teachers involvement, industry attention, and new curriculum units on student learning and attitudes towards science.

References

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2. Baum, R.M., *California Science Institute Boosts Science Teacher Effectiveness,* Chemistry and Engineering News, American Chemical Society, 1985

3. Taagepera, M., Miller, G.E. and Benesi, A.J., *UCI Summer Science,* Journal of Chemical Institute, 64, 234, 1987

Appendices

A. Science Education Advisory Board Membership, 1995
B. UCI Science Education Programs, Program Components
C. The UCI Summer Science Institute, Titles of Courses Offered
D. Modern Technology Course Outline, 1987
E. Future of Science Conference Program, October 1994
F. Budget Summary 1982 - 1995, UCI Science Education Programs

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Dr. Masayasu Nomura
Dr. Frederick Reines*
Dr. Peter M. Rentzepis
Dr. F. Sherwood Rowland*
* Nobel Laureates

Appendix B

UCI Science Education Programs, Program Components

UCI SCIENCE EDUCATION PROGRAMS
School of Physical Sciences
1995 - 1996 Programs

DIRECTORS: Dr. Mare Taagepera and Dr. George E. Miller

CALIFORNIA SCIENCE PROJECT - Orange County Science Education Network (CSP/OCSEN) August 1996, and monthly meetings during the academic year. OCSEN is a collaborative effort of institutions of higher education (UCI, CSUF, Chapman University and 6 Colleges) with Orange County School Districts. During 1995-1996 OCSEN teams will work in 27 districts on the implementation of the new California Science Framework . Satellite institutes are held at various district sites.

UCI BIOTECHNOLOGY FELLOWS PROJECT - The UCI Biotechnology Fellows Project emphasizes the training of high school teachers in biotechnology concepts with implementation of the new curricula at the school sites.

SATURDAYS FOR SCIENCE - "Molecules Around Us" (under reconstruction) - Four one-hour lecture demonstrations by UCI faculty; designed for 4th, 5th & 6th grade students.

RESEARCH ON DEVELOPING CONCEPTUAL UNDERSTANDING IN SCIENCE - designed to involve science teachers and UCI undergraduates in a collaborative research project with K-12 students.

"FUTURE OF SCIENCE" CONFERENCE - October 14, 1995. A *Science Update Day* for science teachers. Designed to provide a quick overview of advances in science by scientists at the forefront of their subject areas; progress on research in developing conceptual understanding in science; and the latest developments in science education for the 1990's.

SCIENCE/TECHNOLOGY/SOCIETY (STS) - A project designed to establish a permanent science, technology, and society network in Orange County to provide continuous updating of science and technology issues in middle and high school curricula. Information available upon request.

"OUR CHANGING WORLD" BIOTECHNOLOGY PUBLIC LECTURE FORUM November, December 1995; January, February, March 1996. A series of public lectures by prominent UCI scientists at the forefront of their research.

OUTSTANDING HIGH SCHOOL SCIENCE STUDENTS - Spring, 1996. Thirty outstanding high school students in each of the fields of chemistry, physics and biology are brought to UCI for four days and introduced to the laboratories and research techniques at the university level. The students are selected from more than ten local high schools.

OUTSTANDING HIGH SCHOOL SCIENCE TEACHERS AWARDS DINNER - May, 1996. A dinner to honor and recognize Orange County teachers of chemistry, physics and biology.

ORANGE COUNTY SCIENCE FAIR AWARDS - May, 1996. The UCI Science Education Advisory Board recognizes outstanding students, science teachers, as well as high and middle schools for their outstanding performance at the Orange County Science Fair.

UCI SUMMER SCIENCE INSTITUTE - August 1996. Three week institute and year-round programs during the academic year. The UCI Summer Science Institute offers a comprehensive selection of courses to suit the needs of elementary, middle and high school teachers. Registration and information will be available in March 1996.

INTERNET/WORLD WIDE WEB for K-12 Teachers of Science: http://www-sci.lib.uci.edu/SEP/SEP2.html UCI/SEP home page is visited daily by more than 5000 people from around the world; provides descriptive links to science materials on the Web to find images, movies, tutorials, text descriptions, and databases for direct application in the classroom. More than 1500 links are sorted by category, subcategory, science topic, and grade level so the teachers can access the appropriate science resources in just a few clicks.

THE UCI SUMMER SCIENCE INSTITUTE

Founded 1981 for teachers of science, K-12

Titles of courses offered in past years

A) ELEMENTARY PROGRAM

1. Matter (Physical Science)
2. Our Changing Earth (Earth Science)
3. Physical Science, Energy
4. Physical Science, Mechanics
5. Life Science/Adaptation
6. Life Science/Ecosystems
7. Leadership Training
8. Environmental Science (Earth Science)
9. Demonstration Lessons
10. Independent Studies

B) MIDDLE AND HIGH SCHOOL PROGRAM

1. Human Biology
2. CHEMCOM, (Chemistry for the Community), level I & level II
3. Oceanography
4. Project Physical Science
5. Conceptual Chemistry
6. Conceptual Physics
7. Conceptual Biology
8. Modern Unified Science/Life Science
9. Modern Unified Science/Physical Science
10. Molecular Biology
11. DNA for Beginners
12. Biotechnology/ Research Frontiers and Bioethics
13. Modern Technology/Science, Technology & Society
14. Related Science in the Classroom
15. Science Leadership
16. Science/Technology/Society
17. Special Topics in Curriculum and Research Updates
18. Radiation & Society
19. Water & the Environment
20. Demonstration Lessons/Science Theater
21. Independent Studies

A typical Institute consists of three elementary and three to four upper level courses plus Demonstration Lessons and Independent Study. The courses may all be taken for professional growth credit, a maximum of 9 quarter units is allowed in any summer. All courses are team taught by an academic scientist and a science teacher from K-12. The classes are a balance of lecture, demonstration/hands-on activities and implementation in the teachers' classrooms. Ample time is allowed for sharing and for networking both in the individual courses and within the Institute. Participants are teachers of science from elementary, middle, and high schools. Teachers have attended from various parts of California and from Estonia, Austria, Italy and the United Kingdom. The Institute is funded by the UCI Science Education Advisory Board and from fees paid by local school districts.

Science & Mathematics Pre-College Education Programs
School of Physical Sciences, University of California, Irvine, CA 92697-4680
(714) 824-6390- FAX (714) 824-7621

Appendix D

1987 COURSE OUTLINE: MODERN TECHNOLOGY

Week one: focus: Modern Technology in the Service of Man

Impact of Technology on the History of Civilization
William R. Griffin, Project Manager Nuclear Waste Repository, Fluor Technology, Inc.

What Aerospace and Military Research Contributes to the Civilian Economy
Dr. Jeffrey Glassman, Chief Scientist Industrial Electronics, Hughes Aircraft Company
Guided Tour and Lecture: McDonnell Douglas Space Center

Symposium on New Materials (afternoon session)
Faculty, UCI School of Physical Sciences

Destructive Earth Movements
Dr. Marion Reed, Senior Research Associate, Chevron Oil Field Research Company

Exploring Natural Resources with Oxygen Isotopes
Dr. Brian Smith, Senior Research Geologist, UNOCAL

Week Two: focus: Problems and Solutions

The Satellite in the Service of Man
Dr. Peter B. Landecker, Space & Communications Group, Hughes Aircraft Company

Off-shore Platforms and Environmental Concerns
Dr. Anne Holmquist, Research Biologist, Chevron Oil Field Research Company

Remote Sensing
Dr. Floyd Sabins, Senior Research Associate, Chevron Oil Field Research Company

Robots in the Operating Room
Dr. Ronald Young, Chief Neurosurgeon, UCI Medical Center

Guided Tour and Lecture: Beckman Laser Surgical Institute at UCI

Hazardous Waste Strategies
Timothy P. Landis, Environmental Research & Technology, Inc.

The Technology of Hardening Metals by Lasers
Roy J. Yeager, Vice President, Engineering Smith International

Earthquakes: Why, How, When?
Dr. Thomas L. Anderson, Senior Technical Manager Fluor Technology, Inc.

A Walk through a Hazardous Landfill Clean-up
Dr. Lisa Anderson, Research Engineer Chevron Oil Field Research

Week Three: focus: Nuclear Energy, Challenges and Problems.

WHAT MAKES NUCLEI TICK? Basic introduction to nuclear structure and energies, radioactivity, biological effects of radiation.
Dr. G.E. Miller, Reactor Supervisor, UCI

HOW DO REACTORS REACT? Basic introduction to nuclear reactor physics and chemistry. How to build, start up, and shut down a reactor!
Dr. Patricia. J. Rogers, Assistant Reactor Supervisor, UCI

A NUCLEAR VIEW OF LIFE The use of radioisotopes in diagnostic medicine, including psychiatry.
Dr. P.A. Jerabek, Adjunct Assistant Professor, Psychiatry and Human Behaviour, UCI

NUCLEAR POWER IN SOUTHERN CALIFORNIA How do we know what effects it has?

Dr. Bob Grove, Environmental Research - Development Supervisor

Dr. Jeanne Leslie, Environmental Monitoring Group Southern California Edison Company

Guided Tour and Lecture: San Onofre Nuclear Power Plant

HINDSIGHT ON CHERNOBYL: How did it happen? What are the known effects?

Dr. G.E. Miller, Reactor Supervisor, UCI

Appendix E

Science Education Partnerships for the Third Millennium
OCTOBER 29 1994,
BECKMAN CENTER, IRVINE CALIFORNIA

8:00-8:55 AM REGISTRATION & BREAKFAST

9:00-9:20 AM WELCOME
Mare Taagepera, Director, Science Education Programs, UCI School of Physical Sciences; Walter Fitch, Chairman, NRC Regional Initiatives in Science Education (RISE)

9:20-10:10 AM KEYNOTE ADDRESS
Introduction
Ralph Cicerone, Dean, School of Physical Sciences, University of California, Irvine

"Science Education: The Future depends on Us"
Bruce Alberts, President, National Academy of Sciences

10:10-10:40 AM BREAK, NETWORKING, POSTER SESSION

10:40-11:40 AM PANEL DISCUSSION: *STORIES FROM THE FIELD*
Moderator: Maureen Shiflett, Director, NRC Education West
Neil Campbell, Senior Manager, Advance Aerothermal Systems, McDonnell Douglas
James Bower, Associate Professor of Biology, California Institute of Technology
Allen Brown, Dean of Natural Sciences, Fullerton College
Mark Sontag, Sierra Vista School Middle School, Irvine

11:45-12:45 PM LUNCH

13:00-13:50 PM WORKSHOPS I: SUCCESSFUL PARTNERSHIP MODELS (each attendee chooses one)

WORKSHOP A: SCHOOL DISTRICT/UNIVERSITY
Pasadena School District/California Institute of Technology
Project SEED, James Bower, Associate Professor of Biology, California Institute of Technology
Barbara Bray, Teacher, Eugene Fields Elementary School

WORKSHOP B: COUNTY and STATEWIDE NETWORKS
California Science Project/Orange County Science Education Network (CSP/OCSEN)
George E. Miller, Co Director CSP/OCSEN, UCI School of Physical Sciences
Roy Beven, Physics Teacher, MissionViejo High School; Associate Director, CSP/OCSEN
Michael Jacobs, Division Dean, Science, Engineering and Mathematics, Cypress College
Stan Johnson, Dean, Mathematics ~ Science, Orange Coast College
Robert Kelly, Science Teacher, Newport Mesa School District

WORKSHOP C: STATEWIDE NETWORKS
California Science Implementation Network/California Advocacy for Math and Science
Kathy DiRanna, Director, California Science Implementation Network (CSIN)
UCI School of Physical Sciences
Jeffrey McMillan, Chemistry Instructor, Rancho Santiago College
Chris Peoples, Geophysicist, Educational Consultant, Irvine, CA
Judy Woodward, Elementary School Teacher, Los Angeles Unified School District
Dottie Stout, Geo Sciences Instructor, Cypress College

WORKSHOP D: SCHOOL/INDUSTRY

Carver Elementary School/Fluor Daniel
Overview: Lupe O'Leary, Principal, Carver Elementary School
Corporate Perspective: Richard Long, Manager, Mechanical Engineering, Fluor Daniel
Chris Johnston, Computer Scientist, Fluor Daniel
Team Teaching Models: Teachers and Partners

WORKSHOP E: INDUSTRY/UNIVERSITY/SCHOOL DISTRICT

Orange County Science, Technology and Society Network
Mare Taagepera, UCI School of Physical Sciences
Neil Campbell, McDonnell Douglas
C. Mel Bost, Jr., Consultant, Atlantic Richfield Company
Frank Jahn, Biology Teacher, Esperanza High School
Karen Carroll, UCI School of Physical Sciences

WORKSHOP F: SCHOOL DISTRICT/COMMUNITY

Irvine Science Alliance
Dorothy Terman, Science and Mathematics Supervisor, Irvine Unified School District
Marilyn Smith, Community Education Coordinator, Irvine Ranch Water District
Mark Sontag, Sierra Vista Middle School Irvine

2:00-2:50 PM WORKSHOPS II: Mechanics (each attendee chooses one)

WORKSHOP G: HOW TO GET STARTED

Discussion Leader: Barbara Becker, Senior Research Associate, Southwest Regional Laboratory
Setting up Partnerships: Carol Danielson, Supervisor, Technical Publications, Fusion Group,
Terry Gulden, Director, Advanced Materials and Technology,
General Atomics, San Diego
Funding Strategies: Lynne Davanzo, UCI Science Education Programs

WORKSHOP H: THE THREE CULTURES: SCHOOL, POST SECONDARY AND CORPORATE - OR HOW TO WORK WITH TEACHERS, STUDENTS, SCIENTISTS, ENGINEERS WITHOUT INSULTING EACH OTHER

Mare Taagepera, UCI School of Physical Sciences
Glenn Nyre, Senior Research Scientist, Southwest Regional Laboratory
Kathryn Flores, Research Associate, Southwest Regional Laboratory

WORKSHOP I MATCHING EFFECTIVE SCIENCE EDUCATION PARTNERSHIP PROGRAMS WITH YOUR AVAILABLE TIME

Virginia Carson, Co-chair, Dept. of Biology, Chapman University
Bruce Davis, Staff Research Scientist, Chevron Petroleum Technology Company
Maureen Shiflett, Director, NRC Education West

WORKSHOP J: UPDATE ON CURRENT SCIENCE EDUCATION POLICY ISSUES

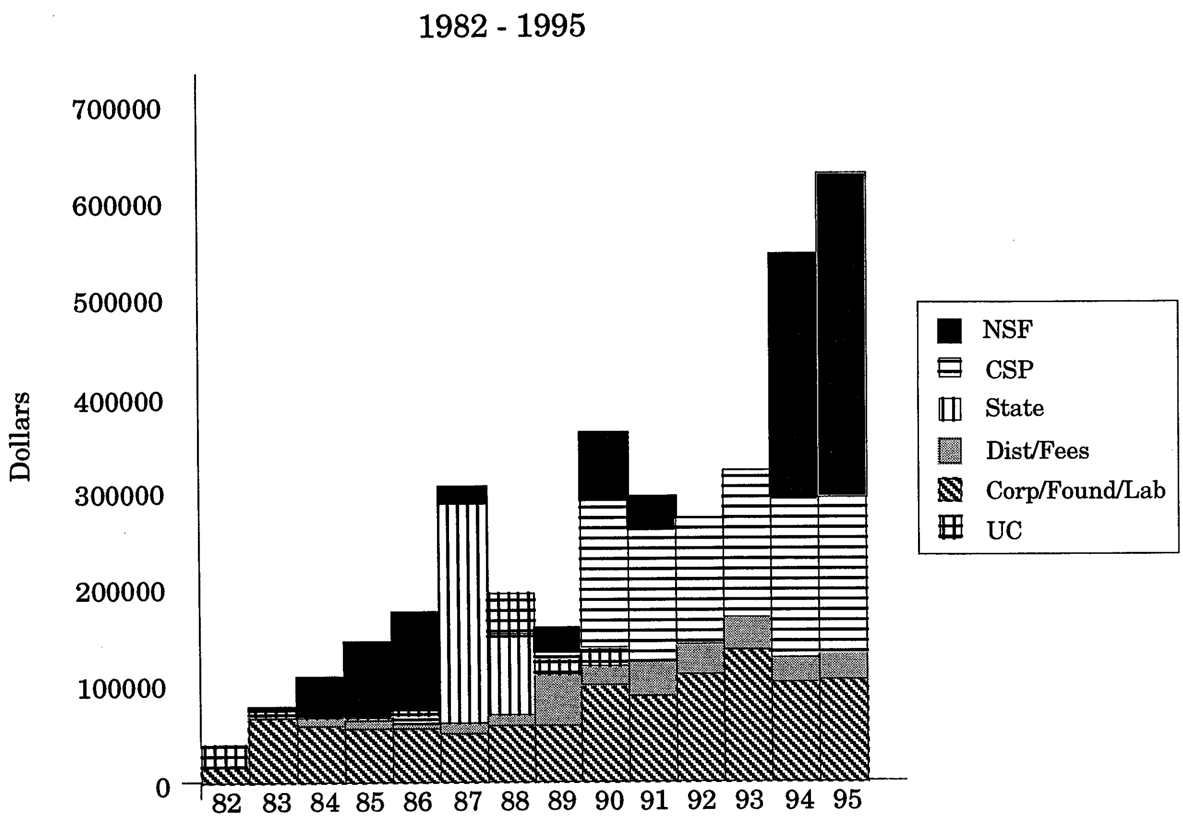
Bonnie Brunkhorst, Associate Director, Institute for Science Education, CSU San Bernardino, Past President, NSTA; Past Chairwoman, Council of Scientific Society Presidents (CSSP)
Tom Sachse, Executive Director, California Science Project (CSP)

WORKSHOP K: NETWORKING LOCALLY FOR MORE EFFECTIVE SCIENCE EDUCATION REFORM: THE SAN FRANCISCO BAY AREA MODEL

Art Sussman, Project Director, Regional Mathematics & Science Consortium, Far West Laboratory

3:00 - 4:00 PM RECEPTION AND SIGN-UPS FOR PARTNERSHIPS

Budget Summary 1982-1995, UCI Science Education Programs



UNINDUS: University-Industry programme for the development of chemistry in Brazil

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January 1996

Introduction

A group of 6 university teachers in the Department of Chemistry in the University of São Paulo, under the leadership of Reiko Isuyama, is actively producing curriculum materials for industry, university courses, secondary school courses and a very ambitious TV course in chemistry for workers.

The formation of the group was not an overnight wonder. It can be traced back over a 15 year period when Reiko Isuyama and Peter Tiedemann became interested in developing low-cost locally-produced equipment for university and school chemistry teaching and collaborating with Professor Krishna Sane's group at the University of Delhi(1). This project was actively encouraged by a senior mentor in their Department, Professor Ernesto Giesbrecht(2).

From these beginnings, they have attracted other members of their Department, local school teachers, industrialists and others in a large range of activities which will be outlined in this chapter, with one specific project being described in more detail.

In 1990 a project was launched with the University of São Paulo, Brazil, and the University of York Science Education Group in the UK, as partners(3, 4). This project aimed to develop strategies through which principles of industrial chemistry and professional (transferable) skills can be taught in a chemical context. Specific objectives included the design of teaching resources for undergraduate students in chemistry concerned with the technological and economic aspects of the Brazilian chemical industry.

As the teaching resources were developed, there was close and fruitful contact with industrialists. An excellent avenue of interaction between university and industry was opened that could be exploited for the mutual benefit of academics and industrialists.

The experience acquired by producing teaching materials in the industrial context also expanded the field of action beyond the university. So in addition to producing workshop material for undergraduate students, the group has become involved in:

- preparing teaching materials to train secondary school teachers, producing resources with them and organising workshops
- training teachers of technical schools
- producing a TV course in science for workers. In Brazil, there are about 15 million people who dropped out of school
- producing a chemistry newspaper for secondary and primary school students.

A much wider programme was thus started. It was called the UNINDUS programme to emphasise unity and interaction between university and industry.

The aims of the UNINDUS programme are to:

- improve the quality of chemists
- improve the interaction between university and industry
- modernise chemistry curricula at school and university.

The UNINDUS programme has branched into a number of subprogrammes, outlined in appendix I.

Resources for teaching industrial chemists

This chapter concentrates on one aspect, the preparation of resources for undergraduate chemistry courses. Most chemistry undergraduates will sooner or later work in or be associated with an industry. However, their courses deal principally with the fundamentals of the science. The relevance of chemical industry is rarely shown to the students and what little they do glean is often from US and European books which can give a very misleading impression for Brazilian students. Furthermore, the courses they undertake are presented in formal lectures and practical classes. There is little chance to gain professional skills, such as to work in a group, to make oral or written presentations, to make decisions.

This project is aimed to help students gain more knowledge about the Brazilian chemical industry **and** to enhance their professional skills. However, such proposals are welcomed in principle by lecturers but rarely adopted in practice because:

- courses are already overloaded with content
- lecturers do not have the appropriate knowledge
- textbooks have only superficial information
- lecturers have no practice in promoting professional skills.

The lecturers, therefore, required help from resources that gave details of the Brazilian chemical industry in terms of what is produced, which processes are used, what are the problems, and what are the challenges, but in a form that allowed for interactive teaching and learning.

These needs can be attained by introducing gradually teaching material into existing courses in which current aspects of the Brazilian chemical industry are discussed.

The project was designed to produce small units of work which can be used during undergraduate courses and allow the ideas engendered in these units to pervade the whole course. These units provide support for effective chemistry curriculum innovation by emphasising aspects of the Brazilian chemical industry and providing opportunities for students to practice a wider range of skills they will need in their professional lives. Professional support for the lecturers was given through training workshops on the use of the resources and with well structured information and suggested teaching strategies. The production of the units and their implementation involved a considerable amount of staff training.

The units of work are described as 'workshops'. They involve discussion between students in small groups, and the solving of problems with no unique answer. Collaboration with the Brazilian chemical industry has ensured that they were up-to-date and relevant to Brazil.

The procedure for developing the teaching material involves a number of steps including visits to industrial producers to collect data on selected production processes, followed by the writing up of material by lecturers and postgraduate students. In one, *Ammonia, Fertilisers and the Fixation of Carbon Dioxide*, all the factors that contribute to emissions of carbon dioxide throughout the stages of production of a fertiliser are examined. Facts and data are given in a step-wise fashion; students are asked to make calculations and deductions for themselves concerning each process stage and to come to some overall conclusion concerning the action necessary for optimisation to minimise production of carbon dioxide.

Each workshop has a different 'story' from industry and the relevant chemical ideas and concepts are selected among these included in the degree course at the University of São Paulo. Also, new concepts that are not dealt with during the course are treated from an industrial point of view. This principle ensures that the new materials replace existing teaching and thus contribute to the development of the curriculum. They also allow the introduction of some elements of industrial principles and opportunities for students to develop professional skills.

The workshops have been designed, written and tested for use in undergraduate courses, by postgraduate students as part of their coursework. This was seen as an excellent strategy for disseminating the approach widely, since many of the postgraduates subsequently become academic staff at other Brazilian universities. By preparing and testing the material they learn considerably more about the Brazilian chemical industry than is needed or implied by the material itself, and they also learn how it can be used to help students to develop skills.

The graduate students are enrolled in a course offered for this purpose and for which they get credit. They work in close collaboration with a lecturer. In this way both present and future lecturers gain experience of the recent innovations in industry and in teaching and learning strategies.

After the workshop is written up, the material is tested with groups of undergraduate students and the material is refined to be user-friendly, following which it is adopted as course teaching material. Normally it is adopted in such a way as to fit naturally into an existing course rather than requiring the creation of additional courses.

Not only have the University staff and students benefited from this work but so too have industrialists. By working closely with the University, they have had help to update and revisit theoretical concepts, to participate in training workshops with other industrial chemists, to work with staff and students in an exciting environment.

Seventeen 'workshops' have been produced and are used in a variety of courses. For example, there is an optional course for third and fourth year undergraduates, over one semester, in which 6 or 7 workshops are arranged. Each workshop lasts for about 4 hours and most are arranged as decision making exercises and they involve students in organising in small groups, in giving oral presentations, in rearranging and presenting data, in writing proposals and accounts. The units are also used in core courses so that all undergraduates meet them. However, the most important result is that the style and philosophy underlying the units are influencing the teaching in the Department.

Other universities are now involved. One of the units has been written in collaboration with the Federal University of Bahia and training workshops have been arranged in the Federal Universities of Rio Grande de Sol and Rio Grande de Norte, in other words from the far south to the far north of the country.

Each of the units is described briefly in Appendix II.

References and acknowledgments

1. see for example, Sane, K.V. and West, D.C., *Locally produced low cost equipment for chemistry teaching,* University of Delhi, 1991

2. Giesbrecht, E., Professor of Chemistry, University of São Paulo; a founder member of the IUPAC Committee on Teaching of Chemistry; winner Bradsted Award, American Chemical Society for distinguished international service in chemical education.

3. Fettis, G.C., Isuyama, R. and Tiedemann, P.W., Entree 92, Proceedings of the Conference on Environmental Training in Engineering Education, Karlsruhe, Germany, November 1992, pp115-124, UETP-EEE, 1992

4. Pontin, J.A., Arico, E. Pitoscio Filho, J., Tiedemann, P.W., Isuyama, R. and Fettis, G.C., *Interactive chemistry teaching units developed with the help of local chemical industry,* Journal of Chemical Education, 70, 223 - 6, 1993

Unindus subprogrammes

The UNINDUS programme started out as a small project entirely directed at chemical education, more specifically, at developing interactive teaching units based on the Brazilian chemical industry. The training of transferable skills was an integral part of the project.

The success of the project over the first three years naturally gave rise to a number of spin-offs, which quickly developed into full programmes. These are summarised below.

Chemistry and Biochemistry

The objective of this programme is to improve research methodology by exchanging senior and junior researchers between Brazilian and British universities. Brazilian scientists learn to conduct research geared to the needs of the local industry, and British scientists become able to judge the constraints under which researchers work in a developing country. Junior researchers are post-graduate students and post-doctoral fellows who through early training overseas will start a career more in accord with the needs of the country.

So far, the University of São Paulo (the campus of the capital as well as the campus of São Carlos), the University of Campinas, and the University of York have been involved in the programme.

Efforts are being concentrated in nuclear magnetic resonance spectroscopy, Raman spectroscopy and electron spin resonance spectroscopy, the latter technique applied to biochemistry. These fields of investigation have been chosen because of considerable overlap of interests of the parties involved.

A workshop, "University and Industry working together for the Country", took place in July 1995 in São Paulo. The workshop was based on case studies of Brazilian and British successful partnerships between university and industry.

TV course Telecurso 2000

The UNINDUS group was invited to organise the chemistry course of the Telecurso 2000, a distance education programme aimed at the 15 million workers who dropped out of school. It includes primary and secondary education, as well as professional training in mechanics. Teaching is in the context of a worker's life and emphasis is on basic skills and citizenship.

This programme was sponsored by the Federation of Industries of the State of São Paulo (FIESP). Its greater objective is to improve the quality of goods produced in Brazil to make them competitive on international markets. This objective will be attained by improving the training of workers.

The chemistry course consists of 50 TV programmes, each 15 minutes long. The story that runs through the whole course is that of a seller of newspapers who is very interested in science and eager to solve the problems of his community.

At the news-stand he meets people from all ranks and classes who help him along, going as far as inviting him to visit them at work. There he meets, for example, chemists and metallurgists, and learns a lot of chemistry. Two books, each of 200 pages, support the TV episodes, develop the subject slightly further and offer questions for self-evaluation. The chemistry course went on air for the first time in May 1995.

Apart from the thrust in industry, schools are using the literature and videos for adult education and employers are encouraging employees to attend evening classes, which can involve up to 30 mature students.

In the future, the main thrust of the Telecurso 2000 are not the programmes broadcast by regular TV channels, but video rooms set up by companies and the Secretariats of Education throughout Brazil. In these video rooms ad hoc-trained guides will offer help to those taking the course.

A measure of its success is a new developed programme of TV episodes which are being commissioned by the São Paulo state education authorities, to complement the first set of TV programmes.

Training of secondary school teachers

Secondary school teachers have been trained in the techniques of teaching in context, especially industrial context, and in developing transferable skills in pupils. For this purpose some of the interactive teaching units based on the Brazilian chemical industry that developed earlier were reviewed in the light of the chemistry content, and more applications and experiments were included.

Contact with the Secretariat of Education of the State of São Paulo has resulted in a plan for teacher training on a large scale.

Training teachers of the National Service for Industrial Apprenticeship (SENAI)

Teaching units similar to those of the previous item are being used for inservice training of teachers of SENAI schools for technicians supported by the Federation of Industries of the State of São Paulo. It is the biggest and best educational organisation of its sort in Brazil. It runs more than 900 schools, in almost all Brazilian states, and has a total of about 2.5 million students. It encompasses all technical fields of activity, including chemistry.

Industrial course at the University of São Paulo

An elective course that consists entirely of workshops based on the interactive teaching units developed in the project is offered at the University of São Paulo. Industrialists help run the workshops.

Newspaper for secondary school students

A four-page newspaper called RE-AÇÃO (RE-ACTION), is written by undergraduate students, under the supervision of UNINDUS staff, and directed at secondary school students. Stories cover the world of teenagers and are written in their language. Subjects from recent issues deal with diving, rock concerts, Formula 1 motor car races, football, in which the chemistry related to them is unravelled. Currently 15,000 copies are being distributed every month. The newspaper is available on Internet.

Link with the Federal University of Bahia

A link with the Federal University of Bahia (UFBA) has been established to begin disseminating the programme at other locations. UFBA was chosen because it is sited in the Brazilian state with the biggest petrochemical complex, that of Camaçari. There is thus easy access to industrialists who can help to develop teaching units. One lecturer from UFBA spent a year at the University of São Paulo to become fully familiar with the programme and implement it in Bahia.

Link with the University Rio Grande do Norte

A new link with the University Rio Grande do Norte is being set up. Funding has been applied for to allow one of the lecturers to come to USP for a year in order to produce two new workshops.

Revision of secondary school chemistry course

If the Minister of Education approves this latest scheme, the current two books used throughout Brazil to teach chemistry to secondary school students will be revised, a third book will be written and supporting videos will be made. Teachers will be given extensive training and will also, for the first time, be given teachers guide notes. Some of the suggested revised material is being piloted in São Paulo schools. If this project goes ahead, it will be funded by the World Bank.

Industrial Case Studies For Undergraduate Chemistry Courses

1. **Hydrogen: Produce it or Buy it?**
R. Isuyama, P. W. Tiedemann and C. J. Garratt

The unit is developed in the format of a decision making exercise where the student has to play the role of a consultant chemist to a company wishing to make hydrogen to produce nylon salt. The student has to analyse the processes available in Brazil and through comparison of the inputs and outputs of different processes decide which is the most suitable one for the company. Students also analyse the possibility of buying hydrogen, taking into account the physical properties of this gas.

2. **Paints, an Application of Polymers**
P. W. Tiedemann, R. Isuyama and G. C. Fettis

This unit is based on the production of a polymer for latex paints. The substitution of one raw material for a less toxic one is examined from the economic point of view. The glass transition temperature of the new polymer, one of the most important physical properties of polymers, is compared with that of the previously used polymer.

3. **Ammonia, Fertilisers and the Fixation of Carbon Dioxide**
J. A. Pontin, E. M. Aricó, J. Pitóscio Filho, R. Isuyama, P. W. Tiedemann and G. C. Fettis

The chemistry taught in this unit concerns that of ammonia production. However, it is approached in an environmental context - atmospheric reduction of carbon dioxide. The subject is developed in terms of Brazil needing a certain amount of crops to feed the population. The land used to grow these crops can be reduced if fertiliser is used. On the excess land, timber, which will absorb carbon dioxide, can be grown. The amount of carbon dioxide released to the atmosphere in the production of ammonia to make fertilisers to produce the crops is compared with carbon dioxide absorption by forests grown in the excess land. Students can then decide on this evidence whether the application of fertilisers for food production is recommended from the point of view of the amount of carbon dioxide released to the atmosphere.

4. **Production of Chlorine: Present Status in Brazil**
S. B. Faldini, W. Oliveira, R. Isuyama, P. W. Tiedemann and G. C. Fettis

Students examine the possibility of using the process of electrolysis of brine with a membrane cell which is clean, instead of a mercury cell which uses a toxic material. This change is analysed by calculating the total energy involved in the electrolytic process and in concentrating the sodium hydroxide solution. It also examines how the Brazilian industries are reacting to the Montreal Protocol signed by the industrialised countries in order to diminish the emission of CFCs.

5. **Sodium Hydroxide**
W. Oliveira, R. Isuyama, G. C. Fettis

This is based on an industry which produces sodium hydroxide using mercury cells and diaphragm cells. Through this workshop students realise that there are applications of sodium hydroxide that need a high purity product. It is discussed why sodium hydroxide produced in mercury cells has a higher purity than the one produced in diaphragm cells. It is shown how this sodium hydroxide is purified and why it is not possible to achieve 100% purity.

6. **Production of Aluminium**
E. M. Aricó, R. Isuyama, P. W. Tiedemann and G. C. Fettis

This unit deals with the production of aluminium in Brazil. Students look carefully at the specific primary energy consumption for the production of an aluminium can. This analysis shows that a large amount of energy is needed to produce aluminium. Then each step of the Brazilian process of production of aluminium is examined. Comparing the energy consumption for the production of steel cans with that for the production of aluminium cans students realise that the energy needed for making the latter is larger. Students are asked to think why steel cans are being substituted by aluminium cans.

7. **Nitric Acid: How to clean the process?**
A. Viveiros, R. Isuyama and P. W. Tiedemann

In the production of nitric acid by oxidation of ammonia to nitric oxide and thence to nitrogen dioxide, followed by its absorption in water, there is a release of nitric oxide, shown through the stoichiometry of the reaction. In this workshop students analyse the kinetic and thermodynamic possibilities of oxidation of ammonia. Technological problems to reduce the amount of nitric oxide are analysed in order to enable students to propose new methods of reducing NO_x emissions.

8. **The Logistics of Sulphuric Acid**
L. C. Shimidt, R. Isuyama and P. W. Tiedemann

That the source of raw material is the main cause of the ups and downs of the sulphuric acid market is shown to the students through this unit. In this workshop students analyse the case of a company which uses pure sulphur as raw material to produce sulphuric acid, having to compete with others which use sulphur-containing ores. In this company, part of the sulphuric acid produced is used on site, in a plant that needs high-purity acid. The other part is sold. In Brazil, as in the USA, 70% of sulphuric acid is used in the fertiliser industry which does not need pure acid. In the unit a thermodynamic analysis of the conversion of sulphur dioxide to sulphur trioxide is considered.

9. Hydrogen Peroxide: Cost and Demand
R. Isuyama and P. W. Tiedemann

Firstly the high reactivity of hydrogen peroxide is shown. Information about commercial applications follow. Although hydrogen peroxide has large applicability and is a cleaner oxidiser than chlorine, its high price prevents it from being widely used. In order to analyse why hydrogen peroxide is not used on a large scale yet, the production process is examined closely and possible problems during the production are identified. Students conclude that the high price of this product is due to the safety problems that do not allow the construction of a big plant.

10. Formulation from the Point of View of the Textile Industry
D. Daltin and R. Isuyama

The distinction between commodities and specialities is made. Chemicals for the textile industry are by and large specialities. Trends in the use of different fabrics are discussed. The process of making cotton fabrics is detailed, from spinning the thread to weaving the cloth, with emphasis on the chemicals used in each step. Among other things, students discover that it is more economical to gum the warp rather than cope with threads breaking in the loom.

11. Quality Control of a Drug
M. A. La Scalea and R. Isuyama

The synthesis of petidine, an analgesic produced in relatively small amounts by a small local pharmaceutical company, is studied. The seven steps, all batch processes, that lead from the raw materials to the final product, are discussed in terms of the organic chemistry involved, including yields and by-products. To assure the quality of the drug, intermediate products are subjected to chemical analysis. At one point students have to decide whether to let a batch proceed to the next step, based on an actual data sheet from the company's analytical laboratory. ISO 9000 norms are introduced.

12. Recycling Aluminium
R. Isuyama, P. W. Tiedemann and G. C. Fettis

Starting from a simplified diagram of a process of recycling aluminium, students calculate the amount of energy necessary to heat up and melt a certain amount of aluminium. Through the energy calculation students realise that the process of removing paints and lacquers from the cans is self-contained and self-fuelled. The total energy needed for recycling aluminium, compared with the energy needed for the production of primary aluminium, shows the percentage of aluminium cans that should be recycled in order to compensate for high energy consumption of the aluminium production.

13. Ammonia Synthesis: and Economical Alternative

P. W. Tiedemann, R. Isuyama and G. C. Fettis

The high cost of raw materials for the petrochemical and fertiliser industries led to the usage of alternative materials that are economically more attractive. Students examine the effects on the operating conditions of the ammonia unit caused by substituting refinery gas for naphtha as the raw material. Replacing naphtha by refinery gas requires existing equipment to be modified. The profitability of the process in terms of internal rate of return as a function of the difference in price between naphtha and refinery gas is examined.

14. Production of Titanium Dioxide

J. Pitóscio Filho

The supply of raw materials, available in Brazil, and the disposal of by-products for the production of titanium dioxide is considered both from the technological and the economic point of view. Concentrating the product from the ore causes environmental problems. This is a comprehensive example of how a plentiful natural resource should be used taking into consideration its environmental damages.

CONCLUSION

The aim of the conclusion is not to repeat what has been said in the preceeding chapters but to draw together some of the common threads emerging from these five stories.

Purpose

Each of the writers recorded various reasons for initiating their partnerships.

The main reasons which attract industry to join these schemes is their wish to:

- enhance the public debate about science and allied industries
- provide young people with sufficient information to make informed judgements and decisions about careers and the impact the industry has on the world
- bring to life the science taught as part of the curriculum.

There is now a large degree of acceptance in the industrial world that supporting education is different to public relations work and so the resources and courses supported by the industries represented earlier are all driven by the curriculum, whether it is for primary, secondary or tertiary education.

It is equally well accepted in the educational world that young people should develop a greater awareness of the relationship of science to current affairs, societal issues and the role of industry. Indeed, when set in such contexts evidence suggests that students find the science more palatable and are more highly motivated to continue with their studies and to pursue the subject to a greater depth.

It may be that some young people will also choose to consider careers in industry. Certainly industry has consistently been concerned that it competes with medicine, law and accountancy for the best students. Perhaps seeing the challenges posed today by the need of the world's fast growing population's for food, energy, clean water and shelter, through resources which set science into the context of how industrial societies are trying to cope, more students will be lured into making their contribution through science related careers.

Infrastructures

Knowing why you want to embark on a course of action and having the resources to do so are not the same thing. It is noticeable that all five projects are firmly established within other organisations, namely university settings.

The partnerships are without exception between the University host and industry. Industry here can be a trade association and/or private companies. In three of the stories, the partnership also included a government body, e.g. the Chamber of Chemical Industry or Local Education Authority.

The partnerships are formalised through the funding arrangements and in three cases through a Management Committee that includes representatives from all the parties concerned.

The funding is not insignificant as it has to support full-time members of staff, research work, training programmes, replacement costs of bringing teachers from the classroom to participate in the various events, printing and distribution of resources.

Each of the programmes described has been running for a number of years and grew out of small beginnings; sometimes pilot schemes or ad hoc endeavours which, because they have met a need, have developed into significantly sized programmes.

Before establishing similar ventures, an industry-education co-ordinator must clearly identify what the real costs will be and where the financial support will come from. Just as important are the champions and advisors who will help to promote the work and steer along the most worthwhile path.

Outcomes

In most cases, a Centre has arisen as a result of the partnership. Centre, here, is used to mean a collection of people whose responsibility it is to do the work and to see that aims are converted into visible activity and outcomes, and who provide continuity to the programme.

The activities fall into the following categories:

Teaching resources

All of the programmes include resources to be used with students. In the main the emphasis has been upon older students, but the Chemical Industry Education Centre at York has demonstrated that resources suitable for children as young as 5 year olds are possible. The choice of content for the resource is in most cases determined by the curriculum. Where national curricula exist this has had a significant impact on the range of science covered.

However, the views of students are also taken into consideration. Each of the writers has described the need to make use of the students' experience and knowledge and so the contexts for the teaching resources reflect local industries and issues which will capture the interest of students.

However, without industrial support to provide accurate and up-to-date data, the resources would not be nearly as effective. So, although it is always someone from education who designs and writes the material, they work with industrial partners. Wherever possible, the resource writers try to bring in the human component, again to attract the students' notice.

In some of these cases, the resource is an option which teachers can choose to insert into their teaching schedules, in other cases the resources have been adopted as part of the established curriculum and in São Paulo, the resources have been developed into a full degree course which students can opt to take.

The more optional the teaching resources are, the harder the group has to work to see that they are adopted by teachers and introduced into the curriculum.

The resources are aimed mainly at the student, that is, they include activities for the students to do but they also acknowledge that teachers may have little experience or knowledge of either the context or the approach to learning. So teachers' notes to give background information and lesson management are offered.

Professional development

All of the projects discuss the need to educate teachers in the use of the teaching resources. This helps the teacher to gain more understanding about the context and relevant science, and time to think about how they might implement the resource into existing teaching schedules. This process appears to reassure teachers, giving them more confidence to use the resources.

Where industrialists are invited to join the sessions, they gain an increased awareness of the needs of teaching colleagues and their students.

In some cases, it is appropriate to train the industrialists to work with students, especially if they are to go into schools and universities to give lectures or to show visiting groups around the site.

Other activities

Site visits are another popular activity. Again, most of these programmes have considered how to make the most of such events. São Paulo mainly used the visit to inspire their teaching units. In Israel, The Weizmann Institute programme and in the UK, CIEC have endeavoured to ensure that students visiting industrial sites can see behind the stacks and pipes to appreciate the chemistry and how the process is harnessed.

Speakers from industry can enhance science being taught in schools and colleges if the speakers are properly briefed. Again programmes have looked at the support the speakers need to improve the quality of this service.

Evaluation

Finally, each of the groups has not been content to work away on their various projects without considering the effectiveness of what they are doing.

Where funding has been available longer term research studies have been set up. Otherwise questionnaires and interviews with teachers and students have been arranged to both ensure developing materials meet their target and that published resources and completed events are delivering the objectives.

Summary

All of us are trying to enthuse young people for science and, whether they choose to follow a career in science or not, give them a better understanding of where science contributes to the world with which they are familiar.

All of us are committed to our work because we see young people become motivated towards a subject they have previously written off as boring or too difficult. We hear from teachers that their classes are more motivated and are obviously enjoying learning, which in turn brings the teacher satisfaction.

If a new group is thinking about setting up similar programmes we would wish to encourage you in this endeavour and hope you find the information found in this publication of practical value.

Miranda Mapletoft
May 1996