

A RESOURCE-BASED APPROACH TO ChE EDUCATION

R. B. NEWELL, P. L. LEE, L. S. LEUNG
University of Queensland
St. Lucia, Qld, 4067
Australia

THERE IS A GRAVE need to modernize chemical engineering education within universities. This contribution presents the current problems and describes the proposed plan of the Queensland department to implement a scheme for resource-based education in chemical engineering. The financial cost over the period 1984-1989 is estimated to be as high as half a million dollars. Additional efforts of dedication and self-sacrifice by staff are necessary but cannot be quantified.

THE PROBLEM

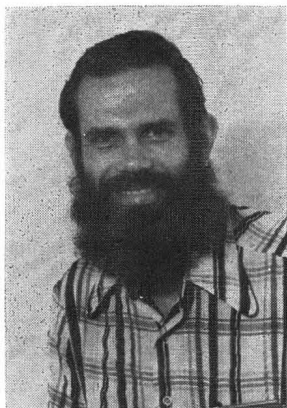
The traditional mode of instruction in chemical engineering over the past forty years has mainly been lectures supplemented by some prob-

lem and laboratory classes, and yet outside the university a major information revolution has taken place. In the light of these changes the time is prudent to evaluate whether better use of new resources can alleviate the problems that are perceived by this department. These problems are touched on in the following paragraphs.

Content. The content of the degree course is expanding in response to rapid growth in both the breadth and depth of engineering knowledge. The rapidly expanding base of engineering knowledge tends to submerge and confuse students' understanding of fundamental principles.

Structural Changes. The graduate in industry has at his command a vast resource of information in databases and computer software packages. He is no longer expected to carry out routine engineering calculations but, rather, has to select the correct computer package and critically evaluate the results. To perform these tasks a student

Bob Newell received his B.Sc. App. and B.E.Chem. from Queensland and his PhD from the University of Alberta, Canada. He also has a Dip.Ed. in Tertiary Education from Monash. He joined the staff at Monash University in 1974, and moved to Queensland in 1980, where he is currently a Senior Lecturer. His early research was in the multivariable control of a pilot plant evaporator, unstable steady state control in a CSTR and multilevel hierarchical optimization. Current interests include optimization of the Australian oil refinery and transportation system, combined fuzzy and deterministic control, and self-tuning and adaptive control of heat recovery systems. (L)



Peter Lee is a Lecturer in ChE. He received his B.E.Chem. from RMIT in Melbourne and his PhD from Monash University in 1980. He worked in the design and commissioning of computer control systems for both continuous and batch plants for three years before coming to Queensland. His early research was on the control of the unstable steady state in an exothermic CSTR. His interests include multivariable self-tuning and adaptive control of fermentation and heat recovery systems. He is also involved in industrial projects involving



waste-water treatment, grinding circuits, and mineral flotation. (C)

Ming Leung holds a Personal Chair and is currently Head of Department. He graduated from Imperial College (BSc) and Cambridge University (PhD). Prior to joining the University of Queensland he spent several years in the oil and chemical industries. His research interests are in gas-solid flow and fluidization. He was the recipient of the Distinguished Lecture Award at the Fourth International Symposium on Freight Pipeline Conference at Atlantic City, and a keynote speaker at the third Engineering Foundation Fluidization Conference at Henniker. He has served as a consultant in the USA, Europe, South Africa, and Australia, mainly on standpipe flow. (R)



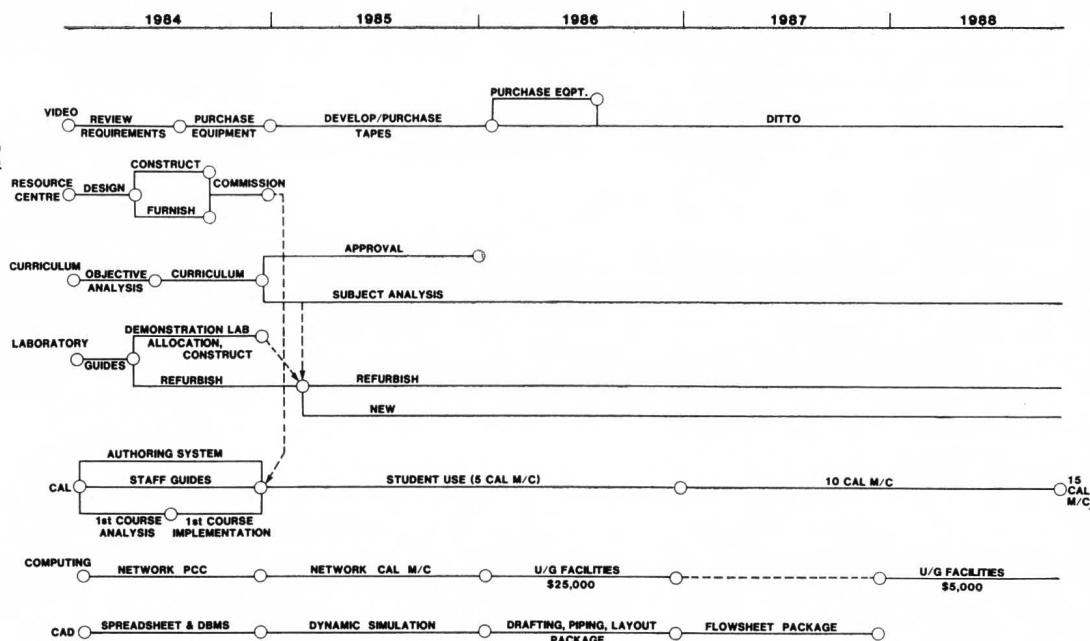


FIGURE 1.

should be thoroughly grounded in fundamentals and exposed to various software packages.

Laboratory. Much of the laboratory equipment and many experiments in the Queensland Department of Chemical Engineering are becoming obsolete. As a result, some of the skills students are being taught are increasingly irrelevant in a modern industrial environment. Indeed, in many areas industrial practice is far in advance of our laboratory experiments.

Student/Staff Ratio. The increasing student/staff ratio means less feedback to students in terms of comments on tutorial problems and practical reports. We need to promote more interactive teaching practices and more efficient use of student-staff contact time, i.e. more opportunity for individual contact and discussion and fewer formal "one-way" lectures.

Literacy. In the age of electronic media, incoming students are less inclined and less able to extract information efficiently from books. While we may decry this trend, we must nevertheless adapt to it. Course notes, directed reading, and information databases are some possible aids in this area.

Motivation. The changing social environment and the secondary school environment are no longer producing students who are "automatically" motivated. We need to introduce instructional techniques to instill motivation as well as concepts

and knowledge. Course and subject objectives and the increased use of interactive media and personal contact will assist.

A SOLUTION: RESOURCE-BASED EDUCATION

To meet the challenge of educating chemical engineers for the 1990s, a fundamental evaluation of the curriculum and the mode of instruction is being carried out in the department. It is recognized that the traditional mode of instruction needs to be reviewed, together with curriculum re-evaluation.

After much discussion in the department during 1983, a plan has evolved to change the mode of instruction towards a resource-based and partly self-paced learning environment.

The plan is to implement the new mode progressively from 1985, after a detailed curriculum re-evaluation and writing of aims and objectives for the course and individual subjects has been carried out. Fig. 1 shows the current planning diagram for the project. The main features of the new scheme are described in the following paragraphs.

1. Reducing the total number of lectures given in the course and reserving the remaining lectures to concentrate on fundamental principles. Currently there are a large number of lectures and students are often unable to discriminate be-

The traditional mode of instruction in chemical engineering over the past forty years has mainly been lectures supplemented by some problem and laboratory classes, and yet outside the university a major information revolution has taken place.

tween fundamental principles and the vast amount of factual material presented.

2. Setting up self-paced laboratories, with long opening hours attended by academic staff. The laboratories will be refurbished to modern engineering standards and experiments will be designed to meet specific objectives. Written or video tape aids will be available to assist students in carrying out experiments. The objectives of these experiments may be (i) teaching of experimental design, (ii) demonstration of difficult to understand concepts, and (iii) simulation of experiments carried out in industry. Currently, students are required to carry out specific experiments at scheduled classes. In a class-like atmosphere with many students working at one time, staff-student contact often takes the form of staff advising students what to do rather than discussion of the results and underlying precepts. By providing better guidance on how experiments should be conducted, more time will be available for discussion of results. The quality of staff-student contact will improve.

3. Setting up a laboratory of demonstration experiments. They will be very simple and easy to operate experiments for illustrating basic principles and a variety of observed phenomena. Many will be transportable to lecture or tutorial and all will be accessible to students whenever they wish. The ability to observe phenomena in the laboratory without the usual long preparation, procedures, and reporting and being able to choose their own time and pace should provide students with motivation and a valuable complement to other resources.

4. Setting up a self-paced computer-aided learning (CAL) laboratory with long opening hours attended by academic staff. Only material specifically suited for CAL will be taught in this mode. Some CAL courseware will be prepared by our own staff and where possible some will be purchased. To significantly reduce the time required for preparation of CAL lessons, the lesson will be prepared with the understanding that a tutor will be available nearby to provide assistance to students. The staff member will be in attendance during opening hours to discuss problems with students providing effective personal contact. Cur-

rently a student is taught through lectures, often at a pace not appropriate to him and at a time when he may not be receptive, and with little or no opportunity for review.

5. Making available a comprehensive range of chemical engineering software packages, physical and chemical properties data package, computer-aided design packages, etc. We are in the process of building up such a library of packages. Students will be exposed to resources comparable to those available in industry. They will be trained in the use of computer databases for access to reference knowledge and in critical evaluation of computer results in a manner required of them as practicing engineers in industry.

6. Making available audio-visual reference material. Much industrial training is presented today with the aid of professional audio-visual aids. Some of these quality aids are also ideal university teaching aids and an attempt will be made to obtain such materials wherever possible. Audio-visual materials, particularly video-tapes, offer the opportunity of bringing the industrial environment to the student when the student requires this information. Presently the student receives this information only from field trips or printed media, the timing of which may not coincide with the need for such knowledge.

CURRICULUM REVISION

In redesigning a course, as opposed to starting from nothing, there are certain pragmatic constraints. In the present case, the department controls only the second to fourth years of the course. This period has been divided into:

- **Background science subjects whose content is generally determined by many votes.**
- **Core chemical engineering subjects which define the basic graduate requirements.**
- **Elective subjects which will be used to enable the student to gain some breadth and also some depth in a particular specialist area.**

The elective specialist areas are mainly determined by the expertise of the staff. The other elective subjects are a "smorgasbord" of subjects offered within and outside the department. The current review is of the core chemical engineering curriculum.

Course Aims. The development of aims for the core course is following the traditional systems approach by starting with a small number of general aims for the graduate:

- Given the task of making a product from given raw materials with the maximum economic return, the graduate should be able to synthesize a suitable integrated set of unit operations (ability to synthesize an integrated process).
- Given the task of designing or analyzing a unit operation or process, the graduate should be able to formulate a model in terms of the basic mechanisms involved (fluid mechanics, thermodynamics, heat transfer, mass transfer, reaction kinetics) and to solve the resulting equations to determine conditions for optimum performance or performance for given conditions (ability to design or analyze parts of a process).
- Given a process plant and a set of environmental constraints, the graduate should be able to determine the optimum conditions for operating the process and to design a measurement and control system and/or operating strategies to maintain the process at the optimum conditions despite disturbances (ability to operate a process).
- Given a task to perform and sufficient resources, the graduate should be able to plan and organize the resources to complete the task in minimum time (ability to perform).
- Given a message to communicate, the graduate should have the written and oral skills to effectively communicate with those above, at, or below his/her level of responsibility and/or expertise.

These global aims have been hierarchically decomposed into about 80 more specific aims.

The next stage was to assign some weighting or importance to each aim. The professional engineering institutions have certain requirements in this regard. Therefore the aims were grouped according to their guidelines which defined some group weightings. Individual aims were then weighted within these groups by staff consensus.

The aims were then reordered into six groups (two semesters each of three years) taking into account the fact that many are prerequisite for others, the available contact hours (which varies somewhat by semester), and the natural grouping by content. This defined subjects each with 2 to 5 aims and a weighting which could be converted into a credit point figure.

Subject Objectives. There is a large literature on objectives and on their preparation, typified by texts such as Rowntree [4] and Briggs [1]. They are generally prepared by hierarchical decomposition and then ordered and represented as flowcharts,

network diagrams, logic diagrams, etc. Himmelblau [2] has done this very nicely and this text is used as the basis of an introductory second year subject.

In the present project, academic staff will be given half-years off their normal duties to prepare objectives and then instructional material for subjects in their area of expertise or knowledge. Eventually each of the core chemical engineering subjects will be defined by a set of objectives relating back to the course aims.

It is hoped that such detailed subject specifications will avoid the overlap and gap problems which usually develop in courses over the years. It is also more likely to succeed in core subjects where knowledge is not at the forefront of research and is reasonably static.

Teaching Strategies. The core section of the course will be resource-based and will combine the strategies of guided discovery and of conver-

After much discussion in the department during 1983, a plan has evolved to change the mode of instruction towards a resource-based and partly self-paced learning environment

sational learning as defined by Pask and Lewis [3].

Both these strategies consider the student to be a problem solver and consider knowledge to be an elaborate structure or network of concepts. The extent of the structure or network will be defined by the subject objectives.

The guided-discovery strategy has the teacher defining the knowledge structure and dividing it to set the students a series of sub-goals which they explore using resources and problems supplied by the teacher. For example, the teacher may define a sub-goal by a lecture and supply a study guide, laboratory experiment, and problem sheets as resources and then assess progress individually in tutorials and by a test. Using this strategy, a typical subject might be divided into six two-week modules, each started with a lecture and followed by two tutorials and a test.

The conversational-learning strategy has the teacher defining the knowledge structure, but allowing the student much more freedom. The student decides upon the order in which material is covered and is free to use supplied resources and

Continued on page 50.

RESOURCE-BASED EDUCATION

Continued from page 39.

to find others. The teacher acts as a resource and an adviser while retaining some assessing and monitoring roles. This strategy is generally used for design projects, and can be used to extend the more gifted students.

CONCLUSIONS

Successfully carrying out this major program of modernization will require

- A commitment by the departmental staff to the new concept
- The willingness of departmental staff to make short-term sacrifices
- The diversion of financial resources to fund the scheme.

Discussion within the department during 1983 has resulted in enthusiastic support from the staff and a commitment by the staff to the concept. As part of the plan each staff member will be relieved in turn of normal duties to be retrained in CAL and video techniques and to prepare new resources. The total financial resources required, including cost for staff retraining, is estimated to be in excess of half a million dollars.

While each element in the proposed mode of operation is not novel, the implementation of the integrated package on a departmental basis in chemical engineering is both new and challenging. This is the beginning. □

REFERENCES

1. Briggs, L. J., *Handbook of Procedures for the Design of Instruction*, American Institute for Research, Pittsburgh (1970).
2. Himmelblau, D. M., *Basic Principles and Calculations in Chemical Engineering*, Prentice-Hall, N.J., Fourth Edition (1982).
3. Pask, G. and B. Lewis, *Teaching Strategies: A Systems Approach*, The Open University Press, Bletchley, Bucks (1972).
4. Rowntree, D., *Educational Technology in Curriculum Development*, Harper & Row., London (1974).

SPATIAL AVERAGING THEOREM

Continued from page 21.

integrals in Eq. 14 in terms of area integrals according to

$$dV_I = -\Delta s \lambda \cdot n_{\beta} dA_I \quad (15a)$$

$$dV_{II} = +\Delta s \lambda \cdot n_{\beta} dA_{II} \quad (15b)$$

There is a minor problem in the use of these relations at the contact point between the surface of the averaging volume and the β - σ interface. As indicated in Fig. 4 the error is on the order of $P\Delta s^2$ where P is the length of the contact line between the surface of the averaging volume and the β - σ interface. Use of Eq. 15 in Eq. 12 along with the estimate of the error

$$\delta V = Q(P\Delta s^2) \quad (16)$$

leads to

$$\frac{d}{ds} \int_{V_{\beta}(s,t)} c_A dV = \lim_{\Delta s \rightarrow 0} \left[\frac{\int_{A_{II}(s,t)} c_A \Delta s \lambda \cdot n_{\beta} dA_{II} + \int_{A_I(s,t)} c_A \Delta s \lambda \cdot n_{\beta} dA_I + Q(c_A P \Delta s^2)}{\Delta s} \right] \quad (17)$$

Since Δs and λ are independent of position, they can be removed from the integrals and in the limit as $\Delta s \rightarrow 0$ we obtain

$$\frac{d}{ds} \int_{V_{\beta}(s,t)} c_A dV = \lambda \cdot \int_{A_{\beta e}(s,t)} n_{\beta} c_A dA \quad (18)$$

Here we have used

$$A_{\beta e}(s,t) = \lim_{\Delta s \rightarrow 0} \left(A_I(s,t) + A_{II}(s,t) \right) \quad (19)$$

and expressing the derivative with respect to s in the form

$$\frac{d}{ds} = \lambda \cdot \nabla \quad (20)$$

quite obviously leads to

$$\nabla \int_{V_{\beta}(t)} c_A dV = \int_{A_{\beta e}(t)} n_{\beta} c_A dA \quad (21)$$

since λ is arbitrary. This is Eq. 7 of Slattery's derivation [15] and in terms of the nomenclature indicated in Eq. 3 we obtain