The Education of the Engineer for Innovative and Entrepreneurial Activity

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The Education of the Engineer
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   'The Role of Project-orientated Studies in Engineering Education'
3. 1975: Lausanne, Switzerland
   'Research in Engineering Education'
4. 1976: Aachen, Germany
   'Continuing Education in Engineering' (jointly with FEANI)
5. 1977: København, Denmark
   'Essential Elements in Engineering Education'
6. 1978: Pavia, Italy
   'Engineering Education and New Professional Requirements' (jointly with FEANI)
7. 1979: Louvain-la-Neuve, Belgique
   'The First Years in Engineering Education'
8. 1980: Paris, France
   'The Education of the Engineer in and for his Society'
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The Education of the Engineer for Innovative and Entrepreneurial Activity

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Welcome

Welcome in The Netherlands. Welcome in Delft. Welcome at our university. As you can experience during your conference, Delft and its university form an attractive synthesis of historic scenery and modern technology. Canals, churches, the market-place and the musea give us moments of rest and reflexion in a turbulent epoch where the influence of scientific progress seems to dominate our ways of life.

Our university has thirteen departments, covering all recognised branches of the engineering science. The number of enrolled students is 11,000, making Delft the largest of the three universities of technology in The Netherlands (Eindhoven 6000 students, Twente 3000 students). The number of personnel is 4000, including 1600 with an academic qualification. Our total budget amounts over Hfl. 400 million, which is for 90% supplied by the government.

The benefits of engineering research and development for society are pluriform in its organisation in Delft: there is a "science shop" through which deprived groups and individuals have entrance to research facilities. There are "multi-disciplinary centres" (e.g. for energy, environmental engineering, medical technology) that surpass the boundaries of the traditional (educational) disciplines in the departments; "transfer-points", participating in a national network, provide a systematic aid to innovative technology for small and medium scale industry, with emphasis on starting up new enterprises. In this respect our institute likes to express its gratitude to you for the forthcoming gathering of international expertise on innovation and entrepreneurship.

It is a pleasure to us to remember that the origins of SEFI go back to the constitutional meeting here in Delft ten years ago. Since then the many inspiring and authoritative conferences on actual issues in engineering education and profession, have certainly been of major influence on decisions within the distinguished institutes in Europe.

We feel honoured by your choice to have the tenth anniversary meeting in Delft: the theme of the conference seems to be particularly tailored to our needs.

It is my sincere hope that its results will contribute to a further reappraisal of the importance of the role of engineering schools for the upkeeping and upgrading of society.

I am convinced that your coming to Delft, to the Delft Institute of Technology, will also find a reward in visits to and discussions with colleagues in the several departments and that it will give you
ample opportunities for a start or a further continuation of scientific cooperation in Europe.

Prof. ir. B.P. Th. Veltman
rector magnificus
Introduction

It was a stimulating initiative of the Commission of the European Communities in August 1979 to invite SEFI to study, on behalf of the Commission, the present state of art of educating the engineer for innovative and entrepreneurial activities in the member countries of the community, especially related to industrial innovation, and to consider how this aspect of engineering education might, if found necessary, be improved.

Early 1980 the report (editor R. Tomkins) containing the results of this study and recommendations by SEFI was completed and published.

The next step was only logical and consistent: the establishment of the SEFI Working Group Innovation in preparation of a SEFI Conference on "The Education of the Engineer for Innovative and Entrepreneurial Activity".

The Working Group Innovation formulated four main themes for the Annual Conference to be held at Delft in 1982 at the occasion of SEFI's tenth anniversary. This conference, the subject of which is closely linked to the title of Tomkins' Report, has indeed been organizes around these four themes, i.e.:

1. Engineering Education and Technological Entrepreneurship
2. Innovation Centres
3. Continuing Education

All themes will be treated from an engineering-viewpoint: the conference is not aimed at innovation but at providing innovative strength and qualities in young engineers, at improving teaching with this purpose in mind, in close collaboration with the living society, and at finding effective ways to make continuing education fertile in this respect.

The four themes will be treated in four parallel sessions each, with introductory contributions prepared by the Working Group. The sessions have been grouped around four Keynote Addresses by internationally known speakers, the usual plenary sessions and General Assembly and some moments allowing participants to think, relax or visit places of interest to them. It has moreover been possible to include time for small group discussions, which should stimulate participants to get even more directly involved in the discussions on the conference subject than during the parallel sessions.

The Programme Committee has been forced to severely select from the vast number of excellent contributions offered. Regrettably as this may be, it is certain that the conference subject has already attracted the interest of a great deal of experts.
The Committee wishes them all a worthwhile and pleasant stay at the old town of Delft.

prof.ir. W.A. Koumans
Chairman Programme Committee
The Education of the Engineer for Innovative and Entrepreneurial Activity
Theme 1. Engineering Education and Technological Entrepreneurship

a. Engineering education and the needs of industry
b. Engineering education and the innovative process
c. Higher education courses on innovation and entrepreneurship
d. Selecting the innovative and entrepreneurial student
e. Developing and improving innovative and entrepreneurial qualities and skills
f. Innovative educational methods: project training, sandwich courses, integrative training

Chairmen: J. de Courcy (Ireland) and Jean Michel (France)
Rapporteurs: Alain Michel (Belgium) and R. Tomkins (Great Britain)
IDENTIFYING INNOVATIVE PERSONS AND DEVELOPING THEIR SKILLS THROUGHOUT THEIR STUDIES: Report of the Subgroup (A2 + A3) of the SEFI Working Group on Innovation

Alain Michel
BELGONUCLEAIRE-Brussels, Belgium

ABSTRACT

Subgroup (A2 + A3) of the SEFI Working Group on innovation was asked to prepare the basis of this conference's sessions on identifying skills that lead to innovation and ways to develop them during the school and university studies. This introductory paper enumerates favorable or discouraging attitudes or circumstances. It outlines arguments to introduce more subjective values into the curriculum, as the innovator is above all an imaginative human being. It concludes with the wish that the conference participants be creative, open-minded and critical during the discussions.

RESUME

Le Sous-Groupe (A2 + A3) du groupe de travail SEFI sur l'innovation avait à établir les bases de sessions de cette conférence visant à identifier les qualités nécessaires au bon innovateur et les moyens de les développer pendant ses études scolaires et universitaires. Cet exposé introductif énumère quelques attitudes ou circonstances favorables ou, au contraire, décourageantes. Il apporte des arguments en faveur de l'introduction de valeurs subjectives dans le curriculum, l'innovateur étant avant tout un être humain imaginatif. En conclusion, il est souhaité que les participants à cette conférence se montrent créatifs, et abordent les discussions avec un esprit ouvert et critique.

ZUSAMMENFASSUNG

Untergruppe (A2 und A3) der in Innovierungsproblemen spezialisierten SEFI-Arbeitsgruppe wurde beauftragt, die Haupthemen der Sitzungsabschnitte dieser Konferenz, welche sich mit dem Beschreiben der Eigenschaften die ein guter Innovator besitzen muss und der Mittel, dieselbe während Schul- und Universitätsjahren zu entwickeln beschäftigen, festzusetzen.

In diesem einführenden Abriss werden einige mehr oder weniger günstige Haltungen und Umstände berücksichtigt, bzw. Argumente angeführt, die das Hineinbringen gewisser subjektiver Werte in das Kurrikulum fördern, wobei der Innovator überwiegend als kreativer Mensch betrachtet wird.

Zum Schluss wird der Wunsch ausgesprochen, dass die Teilnehmer an dieser Konferenz sich selbst auch kreativ zu zeigen und sich an den Diskussionen mit offenem und kritischem Geist zu beteiligen vermöchten.
At the Paris conference in 1980, the SEFI working group on education of engineers for innovation and entrepreneurship was set up and since then, it entrusted its studies to four subgroups which will issue their recommendations at the end of this year. It is our expectation that this conference will bring to our group a maximum of information and for this purpose, we hope you will actively, and hopefully provocatively, participate in the discussions that are proposed in all sessions.

Our subgroup was offered the task of pursuing two of the objectives recommended in Raymond Tomkins's report, i.e.:

A2: 'It would be desirable to identify, as young as possible, suitable persons for the complex careers in industrial innovation and technological entrepreneurship that are discussed in the report. Selection for entry to some specific courses should involve explicit consideration of the abilities and personal qualities required.'

A3: 'A study should be mounted at inter institutional level to consider:

(i) what categories of engineering students should be given courses directed explicitly towards innovative and entrepreneurial development for industry and

(ii) what the curricula for such courses might contain in terms of technology, management science, general studies and personality development.'

Tomkins had already set a solid basis for this work; Chapter 6 of this report on the abilities required, gives a survey of skills and attitudes, and examples of methods to support the development of new ideas. Chapter 7 examines the action of education on the innovative attitude.

Our group has attempted to set up an adequate background for the present discussions. Before defining actions aimed at the selection of candidate innovators and at stimulating their abilities by an appropriate curriculum, we first enumerated factors that might encourage or discourage innovation. On the negative side:

- attitude factors: 'I am ignorant, impotent, excluded, not qualified, scared, not rewarded, ...'.
- lack of experience or even knowledge of the innovation process.
- an education that presents technology as dogmatic and orderly.
- unawareness of a need for innovation e.g. in the development of the Third World, declining industrial areas, etc...
- weak human and social skills.
- lack of strength to 'fight' the rigidity of societies organization.
On the positive side, we find of course all the reverse situations or attitudes. Practically, we can enumerate factors such as:

- awareness of the 'historical' background of previous situations that encouraged or discouraged innovations.
- appropriate industrial experience that can be already introduced to some extent at University level through projects.
- encouragement of practical experience through social and cultural or even entrepreneurial actions during preprofessional years (I recommend reading Brett Kingstone's book on the subject).
- an 'innovation course', that is training in idea finding, new technologies evaluation methods, etc... including education of personal attitudes.
- incentives to innovate during the engineer's career (promotion, fame, money, etc...) but also at university or school level which implies a positive attitude of teachers to the student who brings innovative solutions to the questions asked.

The student must be aware of the fact that innovation will not always be accepted with enthusiasm because it might hurt feelings, or limit the market of company's existing products, etc... What should he then do? A special discussion group is proposed in this conference to exchange ideas on the political - in the broad sense - blocages to innovation.

Reading the abstracts of the papers that will be presented to you during the coming sessions, I think the working group will find ample matter in your discussions to support its final report. First of all, we may be satisfied by the various origins of the papers with contributions from all over Europe and even from the United States. But also, their variety will lead us into most of the topics the working group would like to evaluate: from the fundamentals of creativity to the insertion of its consequences into the curriculum.

Once again, I have to insist on the question of attitudes toward innovative creations. Some of us have written that student outlook is already molded during their school years. This may be true but it is certainly also an easy excuse for developing strictly technical curricula, with little consideration of the development of non technical skills. Others are pleading for or have practised themselves mind opening teaching methods, thus sometimes influencing the whole faculty and not only a single innovation 'course'.

We should question ourselves why people find it necessary to follow innovation or creativity seminars after, and usually outside, university. It might be true that a good 'integralist', an interesting term introduced by A. von Weiss, has first to be a good specialist in a limited domain. But it is also exact, that new methods as described by Don Dekker, can broaden the imagination field and break with restricting habits engendered by years of rational learning.

Is, as Dekker writes, citing Einstein 'imagination more important
than knowledge? or is it impossible as others claim, to create without an extensive understanding of present complex technologies? I maintain that a global view of people's needs, a sensivity to external requirements, imagination to create new solutions to problems old and new, is most important.

In days gone by, the work of the engineer was often referred to as 'l'art de l'ingénieur'. Henry Van de Velde, the architect, wrote in 1901: 'il y a une catégorie de gens que nous ne pouvons priver plus longtemps du titre d'artistes. Leur œuvre s'appuie d'une part sur l'utilisation de matériaux dont l'emploi était inconnu auparavant, d'autre part sur une témérité telle qu'elle dépasse encore celle des bâtisseurs de cathédrales. Ces artistes, ces créateurs de la nouvelle architecture, ce sont les ingénieurs. .... Une chose est belle quand elle est comme la création immédiate et sans arrière pensée d'un homme qui s'interroge pour la première fois sur l'utilité des formes et le résultat qu'on en attend.' A new imaginative design well adapted to its use, created with new materials, unknown before, with daring skill based on knowledge and reasoning. Art in this sense might refer to the skills of the good craftsman; I would connect it to the behaviour of great ancestors like Da Vinci and wish that engineers would forget a little of their mathematics, computerized tools and their rational logical thinking, and open their work to a little more art and creative ingenuity.

Our task as a working group will be to participate during this conference to what I hope will be great moments in the exchange of new ideas. We will later nurture them at leisure and may be some practical recommendations for introduction into the engineering curriculum will be born out of this process.

You probably know that Sartre and Simone de Beauvoir had a deep hate for their favorite ennemy, the engineer: 'Ce n'est pas un hasard, si pour nous l'ingénieur représentait l'adversaire privilégié: il emprisonne la vie dans le fer et le ciment. Il va droit devant lui, aveugle, insensible, aussi sûr de soi que de son équation et prenant impitoyablement les moyens pour des fins'. I am happy to feel that many of you, because you are here, do not exactly fit into this picture. But let us not forget that although teaching is the daily burden or joy of most of us, it is not an end but a means to transform school students into bright innovative engineers. Nevertheless the purpose of these sessions is to seek new ways of education to strengthen the skills we hope to detect.
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PUT 'INGENIOUS' IN ENGINEERING EDUCATION

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'Imagination is More Important than Knowledge', Albert Einstein

ABSTRACT

To meet ever-changing challenges, future engineers will have to recognize and develop their creative skills. It is imperative that we - as engineering faculty - emphasize the importance of these skills. To encourage and build our students' creative skills we must build a creative environment and introduce our students to creative enhancement techniques. Well designed student projects are also an excellent way to develop students' creative skills. If we, as engineering faculty, meet our challenge - teaching both creative skills and analysis skills in the classroom - our students will be better able to meet their future challenges.

RESUME

En vue de satisfaire à des exigences sans cesse renouvelées, les futurs ingénieurs devront reconnaître et développer leurs capacités de création. Il est indispensable que nous, qui assurons la formation des ingénieurs, soulignons l'importance de ces capacités. Afin d'encourager chez nos étudiants le développement de ces capacités de création, nous devons créer un climat propice à la créativité, et leur présenter des techniques stimulant leur ingéniosité. De projets d'étude bien conçus constituent aussi un excellent moyen de développer la créativité des étudiants. Si, dans la formation que nous donnons aux futurs ingénieurs, nous nous montrons à la hauteur de notre tâche en insistant sur les capacités de création comme sur les capacités d'analyse, nos étudiants s'en trouveront mieux préparés pour répondre aux exigences de l'avenir.

ZUSAMMENFASSUNG

Um ständig sich ändernde technische Aufgaben ausführen zu können, werden zukünftige Ingenieure ihr schöpferisches Vermögen erkennen und entwickeln müssen. Als Lehrer der Ingenieurwissenschaften haben wir die dringende Verantwortung, die Wichtigkeit dieses Vermögens zu betonen. Um die schöpferischen Fähigkeiten unserer Studenten anzuregen und zu stärken, sollten wir Wert auf eine schöpferische Atmosphäre im Klassenzimmer legen und den Studenten die Methoden beibringen, durch die sie ihre eigene schöpferische Kraft entwickeln können. Wenn wir als Lehrer der Ingenieurwissenschaften dieser Aufgabe gerecht werden wollen - d.h. in dem wir beide,
sowohl die schöpferischen als auch die analytischen Fähigkeiten lehren - dan werden unsere Studenten besser in der Lage sein, die zukünftigen Aufgabe auszuführen.

1. INTRODUCTION

Ingenuity and creativity are among the traits which bring about breakthroughs and new discoveries. The engineers of the future - our students - will have to use their creative skills to solve the ever-changing challenges of the future. It is imperative that we, as engineering educators, encourage and cultivate our students' creativity.

Engineers or 'ingenieurs' must use their creative skills to find new concepts, new approaches to problems, new problem definitions and be able to conceive unique possibilities. These creative skills are quite different from analysis skills, but they are just as important to solving engineering problems as the analysis skills. Our students should not have to wait until after graduation to discover the need for creative skills. These skills should be integrated into existing courses. The root of the word engineer goes back to the Latin 'ingenium' and we must put ingenious in engineering education!

2. CREATIVITY AND CREATIVE SKILLS

Creativity is part of successful engineering. It is sometimes called invention; sometimes it is developing something which is new and useful to the inventor; sometimes it is combining existing knowledge in a new way and developing an original idea; and sometimes it is inspiration. Creativity is difficult to define; but conceptualizing something new and different is common to most definitions.

These creative skills include problem definition and re-definition, encouraging alternate solutions, communication of ideas and conceptualizing. The creative skills are different from analysis skills which analyze something which currently exists. The creative skills produce something new to analyze.

3. CREATIVE ENCOURAGEMENT

For the creative process to flourish, there must be a receptive environment. Although the 'utopian' creative environment may differ, it should contain these five main factors:

(1) Challenge          (3) Inputs             (5) Time
(2) Exposure           (4) Experiment

The challenge is needed for motivation. The challenge must also be accepted as worthwhile. The engineer must be willing to spend time and/or money to solve it.

Exposure means that all aspects of the problem are studied and
perhaps the problem may be re-defined (either broadened or restrict-
ed).

Inputs must come from all persons or groups who will be affected by the solution.

It may be helpful to try out different ideas, so the opportunity to experiment is a necessary part of a creative environment.

Time is essential. Creativity is not a logical process. The mind needs time to assimilate all of the inputs, exposures and experiments. This incubation period lets the mind work on all the information that we gained, and combine it in various ways with our past experience. Our unconscious minds work on the solution when we are not aware of it - then - hopefully - INSPIRATION!

If we are to encourage creativity in engineering classrooms and, therefore, cultivate our students' creativity, we must consider the factors which will help us create a creative environment.

Creative work needs:

Encouragement - Not - Argument
Help - Not - Hinderance
Cooperation - Not - Competition
Openness - Not - Secrecy

4. THINGS TO TRY

A few guidelines for those introducing creative concepts to their students are suggested below.

'... The tendency in education has been to concentrate too much on correct thinking and too little on originality, too much on problems requiring one solution and one method of working and too little on problems that admit a diversity of methods and solutions.' (3; p.78)

This indicates that more open-ended problems need to be assigned. Even if it is possible to use only one method, the problem can be broadened so there is more than one answer. A statics problem, for example, might be: 'Estimate the load that the bridge over the Wabash River will hold.' Many approximations and assumptions must be made so the problem no longer has only one answer.

Give personal and real world examples of 'the more we know the more we want to know'. Gaining 'knowledge' is obtaining answers to exciting questions. Knowledge is not something we pour into our students' heads through a funnel. Try to teach your students to ask these questions - let them know some of the questions you ask in your own research and the questions of your colleagues.

Encourage your students to practice fluency (producing many ideas), and to think of many solutions. Try 'brainstorming' (lots of ideas - no negative comments).

Trigger their curiosity by asking 'what if...' or 'what would it be like if ...'. Break conventions; break physical laws, daydream
when completing the questions. Allow time to incubate. Repeat the question - see if more creative ideas have been produced.

Lastly, the inventor must verify his own creative ideas - no one else is going to do it for him. He must use creative experiments and/or analysis skills to verify his 'invention'.

5. TRY PROJECTS

Projects are one way to teach both creative skills and analysis skills. Projects come in many forms and sizes. They can be big, hardware oriented projects or a small design report. They can deal with familiar or unfamiliar areas. They can be small (2-3 week) 'fun' projects. Projects have been used for teaching for years. The choice of the project directly affects the amount of creativity required to meet the challenge.

For example, during one quarter, three student projects were assigned. The first one was to design and build a balsa wood pedestal that weighed under 0.1 lb. that would support the greatest load. Since this was a familiar area, the results were quite predictable. Each student could easily visualize what this might look like and they build it accordingly.

The second project was to design and build a mousetrap powered vehicle which would travel the greatest distance (in a relatively straight line). Not one solution quickly comes to mind as to how this vehicle should be constructed. Without any preconceptions, since the subject area was less familiar, the students have to use their creativity to figure out how to get the mousetrap spring to power the vehicle. Several different design concepts emerged. Small wheels, large wheels, a pendulum type motor with two wheels. Old records were the most popular wheels.

The third project was to pick up dollar bills which were placed on every other step of a stairway. (A dollar on every step posed a possibility of losing too much money.) No adhesives were allowed. No one knew what a 'dollar bill picker upper' looked like! The vehicles they created were fantastic! Not one looked like any other! This area was totally unfamiliar and the results showed it.

The use of student projects is certainly not new. However, the projects must be carefully planned if creativity is to be encouraged. The project should be in an unfamiliar subject area so that no solutions pop immediately into the student's mind. The students must then use both their creative skills and analysis skills to challenge the project.

6. ON ENCOURAGING INGENIOUS IN ENGINEERING

Creative ideas are a delicate, fragile concept - they can be easily crushed. There are many techniques which can be used to enhance the creative abilities of an individual or a group (1, 2, 3, 4, 5, 6). These techniques have been described in the references and will not be discussed in detail in this paper.
Students shouldn't have to find their way alone through a 'jungle' of obstructions to find their creative oasis — we should guide them and help them in this endeavor. If we can't help — at least we should not hinder their creative development. As stated by A.D. Moore (4; p 26), 'In fact, I suspect that the taking of a degree in science or engineering may, in many cases, do more to stifle creativity than to stimulate it.' If, however, we choose to encourage and stimulate creativity in engineering design, we must know what traits to encourage and also what not to do.

Creativity can be thought of as analogous to the blossoms in a flower garden. Several tasks must be performed before the 'seeds' mature into plants with beautiful blooms. First the seed (creative idea) must be planted. The garden must then be fertilized, watered, weeded and sprayed while the plants is maturing.

The fertilizing and watering are like creative enhancement techniques. They help the creative ideas grow.

The weeding and spraying eliminate the weeds, diseases and bugs which will keep your plants (ideas) from growing and flowering. The weeds and bugs can be thought of as the external influences which prevent our creative ideas from maturing.

In many cases, we may not even 'plant the creative seed'. We all have internal hang-ups or blocks which inhibit our creativity. These blocks are quite prevalent and include our habits, background, surroundings, temperament, and environment.

We must recognize internal and external creative clogs and help our students recognize and eliminate or understand and work around their mental blocks.

7. CREATIVE AIDS

Creative ideas can be encouraged as fertilizer and water help nourish the seed.

Two very important attitudes which encourage creativity are:

'Deferring Judgment of an Idea'
and asking
'What's good about it?'

Another statement is 'only positive comments allowed'. This eliminates early judging (which is almost always negative) and gives the creative idea some time to grow and get stronger. More importantly, by looking at the good points of an idea, the positive attributes of several ideas (partial solutions) can possibly be combined to produce a super solution! Use the best parts of all ideas! It is usually difficult for engineering educators, businessmen, parents, etc. to defer judgment because we have been schooled in a non-creative environment and we are sure that we are right! Both of these factors tend to produce premature judgment. James Adams (1; p 57) says, 'In the university, much scholarship is devoted to judgment rather than creativity'.

It is difficult to 'defer judgment' and ask 'What's good about
it?' But, it will help you and your students extract the 'best' from an idea. Just as trying to get hot and cold water out of a faucet at the same time produces luke warm water, we can't create ideas (be hot) and judge these ideas (cold and calculating) simultaneously.

8. OTHER CREATIVE AIDS

Brainstorming, synectics, morphological analysis, list making and attribute listing are a few of the techniques which can be used to repress our negative creative habits and encourage a creative climate. They force us to expand the number of ideas and combinations that we can produce.

These techniques apply to both group and individual use and are very helpful. For further information on these creative enhancement techniques, please consult the references.

9. SOME CREATIVE CRIMES

There are many phrases we hear and/or use daily which severely limit creative thought. Some of them are listed below as quotes. When was the last time you heard?

'I like that, but ---'
'We tried that last year.'
'It will never work.'
'Get serious!'
'Give me the facts.'
'I want your decision now!'
'Come back down to earth.'

Although each of these statements may be necessary at a given time, they all severely constrict creativity because they have a negative connotation and tend to belittle the idea and/or the person who created the idea.

10. SUMMARY

Creativity - originating a new, unique idea - is a process which is usually omitted in engineering education. If our students are to meet the challenges of the future head on, they will need creative skills as well as analysis skills. Creative skills are subjective and hard to quantify. It is difficult to determine whether or not the student has become 'more creative'. There is no reason to ignore teaching creative skills because it is difficult. Examine and enhance your own creative skills and meet the challenge to enhance and improve your students' creative skills. We as educators are left in a dilemma which is well stated by G.F. Kneller (3; p 79), 'On the one hand, they must train logical, rational thought; on the other, they must foster fluency and freedom of mind and the ability
to tap the springs of the creative subconscious.' By meeting our challenge our students will be better able to meet their future challenges!

Our students' creative abilities can certainly be improved. If only by our recognizing that we do not have to teach people to be creative; we just have to quit interfering with their being creative. Even to 'quit interfering' we must know what to stop doing! This paper has given you some guidelines and sources to study. These are a first step if you accept the challenge to Put Ingenious In Engineering Education. As Plutarch said, 'The mind is not a vessel to be filled out but a fire to be kindled' and I hope this has started your creative burning!

REFERENCES

In december 1981, the annual congress of the 'Conférence des Grandes Écoles' was devoted to 'New products and Design'. In addition to conferences, small discussion groups dealt with various subjects, contests were organised in order to stimulate this field of activity in the French Grandes Écoles.

Herewith are summarised some of the conclusions, of the questions raised and also of the measures considered in the Grandes Écoles.
Ces 113 écoles forment annuellement 12,000 diplômés. Réunissant des 'opérateurs de formation', la Conférence étudie les problèmes communs, suscite une concertation, définit les grandes lignes de solutions pour l'amont, les concours, l'enseignement, les ressources éducatives, l'évolution de la pédagogie, la recherche, les relations internationales. Elle organise des journées d'études dont l'objet s'est peu à peu élargi. Partant de sujets d'intérêt souvent interne (motivation des élèves et innovations pédagogiques), elle a abordé ensuite des sujets comme l'environnement, l'audiovisuel, la documentation, l'enseignement des langues, l'enseignement et la recherche en énergie.

En décembre 1981, la Conférence des Grandes Écoles a consacré son congrès annuel à la conception de produits, considérant que ce thème était primordial pour la formation des ingénieurs et l'avenir industriel du pays. L'objectif du congrès était d'établir un bilan, d'analyser les besoins, et d'accroître les relations Écoles-Industries dans le domaine de la conception et du design industriel.

À l'occasion du congrès, la Conférence des Grandes Écoles et le Ministère de la Recherche et de la Technologie ont organisé deux concours destinés à encourager la conception de produits dans les écoles d'ingénieurs.

Le premier concours doté de 5 prix de 20,000 F chacun était consacré aux projets effectivement réalisés au cours des cinq dernières années.

Les produits ou procédés retenus au titre de ce concours sont:

- Le véhicule TUM (Transport Urbain Minimal) de l'École Nationale Supérieure de Mécanique de Nantes.
- Le tricycle électrique de l'École Nationale Supérieure d'Arts et Métiers.
- Le procédé de traitement de surfaces métalliques au moyen de procédé oxyfluorés du phosphore V de l'École Nationale Supérieure de Chimie de Montpellier.
- Le procédé de préparation industrielle de carbonate de calcium de grande pureté de l'École Nationale Supérieure de Chimie de Lille.

Le second concours concernait les projets à mettre en œuvre ou à réaliser au cours de l'année 1982; les prix revêtent la forme d'une aide financière pour un montant global de près de 1,5 millions de francs, destinée à faciliter la réalisation des divers projets présentés.

Les projets retenus au titre de ce concours sont:

- Le fauteuil pour handicapé de l'École Supérieure d'Ingénieurs en Électronique et Electrotechnique.
- L'hélicoptère bi-place de petite puissance de l'École Nationale d'Ingénieurs de Saint-Etienne.
- La pasteurisation de lait à énergie solaire de l'École Nationale Supérieure d'Arts et Métiers.
- Le sécateur autonome portatif de l'École Nationale Supérieure d'Arts et Métiers.
- Le projet d'unité de préparation de café-boisson de l'Institut National des Sciences Appliquées de Lyon.

Au cours du congrès, une dizaine de conférences plénières, neuf tables rondes et de multiples visites d'établissements de formation et de centres de création industriels ont permis aux participants de réfléchir sur les moyens à mettre en œuvre pour développer la créativité technologique dans la formation des ingénieurs : les principaux points que l'on peut retenir de ces échanges sont les suivants :

a) Tout d'abord dans l'enseignement secondaire, tous les participants se sont accordés pour noter l'incompatibilité entre l'approche abstraite et spécialisée des problèmes due à une division traditionnelle par discipline et la vision globale, systémique, que suppose la création de produits. De plus, généralement, la place laissée aux activités artistiques et de création est dérisoire. Il faut donc proposer tout au long de la scolarité des activités de création ou de construction, introduire des objets réels pour des études, des analyses, telles que démontage et remontage, faire une place de premier plan à l'enseignement artistique et sensibiliser les enseignants à la création industrielle par des conférences, séminaires, visites, stages, ....

b) Au niveau de l'enseignement supérieur et de l'enseignement en général, il convient de rendre effective la présence du monde industriel et de la technologie dans la plupart des activités.

Introduire des méthodologies spécifiques pour la création de produits peut faire pénétrer un courant d'idées nouvelles dans les approches classiques de l'enseignement : ainsi l'approche globale systémique doit venir en complément de l'approche analytique à condition de s'appuyer sur une réalité concrète et un produit à concevoir.

Les techniques ou démarches qui s'intègrent à cette approche sont diverses : méthodes de créativité, bionique, analyse de la valeur, ergonomie, design industriel, esthétique, technologie, communication, maquettes, processus et procédés de production, conduite de projet, ... Autant d'outils que l'ingénieur devrait posséder et qui sont parfois négligés faute de trouver à s'inscrire dans les programmes.

S'intéresser aux produits conduit aussi à s'interroger sur les problèmes de sécurité, de qualité, de maintenance, de récupération, bien souvent passés sous silence.

La structure d'un projet de conception de produit permet d'établir un nouveau fil directeur entre les disciplines enseignées de façon isolée. Elle permet aussi d'introduire une forme d'apprentissage
innovateur, de concilier ceux qui veulent faire passer un maximum de connaissances et ceux qui veulent enseigner des méthodes.

c) Pour développer la création de produits, il faut savoir remettre en cause les produits existants, il faut savoir séduire et non plus seulement produire, il faut épanouir le talent et l'art, introduire des 'fissures logiques' ou des failles dans la cohérence du système éducatif: mélanger les méthodes intuitives et les méthodes déductives afin de sortir des sentiers battus.


e) Pour arriver à la maîtrise de la conception de produits, plusieurs chemins sont possibles: ceux qui commencent par l'art et ceux qui commencent par la technique, mais chacun de ces chemins dans l'état actuel du système d'enseignement est à completer par autre chose. En effet, la maîtrise de la conception de produits n'est pas seulement dans la personne du créateur mais répartie de plus en plus dans l'ensemble de l'organisation industrielle: pour développer la culture technique, il ne suffit pas de disposer de quelques personnes cultivées; il faut une société où tous (ingénieurs, techniciens, ouvriers) soient motivés pour penser, et échangent leurs connaissances, leur expérience, leur technicité respectives; des ateliers de création doivent se substituer aux ateliers de production. Cela suppose chez les ingénieurs des qualités pédagogiques, des qualités d'écoute, des qualité d'communication. L'exemple japonais est éloquent sur ce point.

f) Il faut souligner d'autre part l'importance de la formation des formateurs pour la conception de produits, de leur place dans les structures, des carrières qui leur sont offertes, de leur capacité d'animation et de leur pluridisciplinarité. L'accent est mis également sur le rôle de la formation continue pour sensibiliser les différents partenaires industriels au design et en particulier les décideurs.

g) L'innovation technologique suppose des moyens financiers importants y compris dans l'enseignement. En effet, la formation à la créativité n'a de sens qu'appuyée sur des expériences concrètes vécues par les élèves. C'est pourquoi l'Agence Nationale pour la Valorisation de la Recherche (ANVAR) va encourager en France la créativité chez les élèves des écoles d'ingénieurs par des aides à l'innovation. Ces aides pourraient servir à fabriquer le prototype du produit conçu par les élèves et dont ils auraient réalisé eux-mêmes le dessin et précisé les spécifications de construction. Dans
le cas de projets très coûteux, elles permettraient tout au moins la réalisation d'une maquette. Elles offriraient également la possibilité de protéger les inventions en finançant les dépôts de brevet. A ce sujet, de nouvelles procédures vont devoir être mises en place et une réflexion conduite pour situer la place de chacun des partenaires dans la propriété industrielle: établissement de formation, industriel, enseignant, élève.

On s'est interrogé pour savoir s'il fallait mettre au point des structures de gestion particulière permettant de prendre en compte cette innovation dans les écoles.

h) Enfin, il est clair pour tous que des relations étroites doivent être tissées entre l'industrie (grands groupes, et surtout petites et moyennes industries) et les écoles de formation, aussi bien sur le plan de la recherche que sur celui des études, des projets, etc., ... car à l'avenir, le problème ne sera pas de savoir comment produire mais que produire. Plusieurs revues technologiques se sont déclarées prêtes à assurer toute la publicité nécessaire pour mettre en relation créateurs et utilisateurs.
0. INTRODUCTION

Innover et entreprendre sont des maîtres-mots de notre société: l'innovation et l'esprit d'entreprise sont, pour nos industries, des voies majeures pour se développer, se diversifier, créer des emplois et exporter.

Pourquoi n'innove-t-on pas davantage, pourquoi le goût d'entreprendre semble avoir disparu? On peut parler de blocages:

a. D'ordre structurel et institutionnel, dont il ne sera pas question ici.
b. D'ordre psychologique et psychosociologique, contre lesquels un établissement d'enseignement et de recherche peut avoir une action.

Les élèves-ingénieurs, au cours de leurs études (stage longue durée/projet) et à fortiori après leur insertion professionnelle, peuvent être des vecteurs de transfert de technologie et participer à l'évolution d'un certain nombre d'habitudes et de mentalités face à l'innovation et à l'aptitude à entreprendre.

Comment une école d'ingénieurs peut-elle favoriser le développement personnel des futurs ingénieurs et créer un climat favorable à l'épanouissement de personnalités innovatrices?

Il nous a semblé à Compiègne que ceci ne pouvait être seulement le fait de tel ou tel enseignement spécialisé sur l'innovation, la créativité, etc.; certes important et nécessaire, mais que le système d'éducation dans sa globalité devait concourir à donner le goût et l'aptitude à innover et entreprendre.

C'est dans cette perspective qu'il nous a semblé essentiel:

a. De laisser une part importante à l'initiative des élèves, au travail et à la réflexion personnels.
b. De favoriser dès la première année d'études supérieures les contacts des étudiants avec la pratique des méthodes de l'ingénieurs sur des problèmes réels.
c. De favoriser également la formation au contact de la recherche.
d. De donner à l'étudiant une formation plus proche de son futur environnement professionnel grâce à des stages de longue durée en milieu industriel.
1. DONNER PLUS D'INITIATIVE AUX ÉTUDIANTS

La vie à l'Université est une période de transition vers la vie active au cours de laquelle l'ingénieur aura à prendre des responsabilités. Il y a lieu, par conséquent, de l'y préparer dès son entrée à l'Université, de créer chez lui un état d'esprit qui l'amène le plus rapidement possible à faire des choix, ceux en particulier relatifs à sa propre formation dans une perspective orientée vers l'avenir. Il faut que l'étudiant passe d'une attitude passive et dépendante à une attitude active qui lui permette de mieux exploiter les possibilités qui lui sont offertes. C'est en ce sens que l'ingénieur de Compiègne aura très rapidement à élaborer dans un cadre lui assurant une formation équilibrée, son propre cursus lui permettant ainsi de suivre les enseignements correspondant à ses goûts, à son projet de carrière.

Pour ce faire, un enseignement de type modulaire, en unité de valeur semestrielle, a été mis en place. En fonction de la spécialité qu'il envisage, l'étudiant peut donc choisir les unités de valeur qu'il va suivre. Ce choix est, bien sûr, guidé par quelques contraintes, en particulier il importe que le futur ingénieur ait un profil de formation équilibré. Pour ce faire, il doit acquérir un nombre minimum d'unités de valeur dans chacune des 4 composantes de la formation : Science et langage scientifique, technique et méthode, expression et communication, culture générale, le nombre minimum d'unités de valeur qu'il doit obtenir pour le diplôme d'ingénieur étant supérieur à la somme des nombres minimum de chacune des composantes.

Dès son premier semestre à l'U.T.C., une unité de valeur 'réalisation' est proposée à chaque étudiant. Les objectifs de cette U.V. sont essentiellement de favoriser l'initiative et la prise de responsabilité de chacun face à un problème nouveau, concret et de lui permettre d'utiliser les connaissances déjà acquises, de lui faire prendre conscience des conséquences humaines, sociales, économiques ... d'un projet technique quelconque. Ceci signifie que dans la pratique, les étudiants doivent apprendre à rassembler une documentation (bibliographie, catalogues, devis, etc.) à planifier un travail, à aboutir à une réalisation concrète et à la présenter, à justifier les solutions adoptées.

On constate que l'U.V. 'réalisation' introduit dans la perception des étudiants une double rupture : ils perçoivent non seulement que le système U.T.C. est différent du système scolaire antérieur, mais que, eux-mêmes, doivent désormais être différents.

Les sujets de réalisation sont assez divers : construction d'appareillages, montage audiovisuel ... Lorsque cela est possible, les projets d'intérêt commun sont regroupés en ateliers, lesquels élaborent leur propre organisation (budget, planning ...) sous la responsabilité d'un enseignant. Les réalisations peuvent être proposées par des enseignants ou par des étudiants ou résultent parfois de demandes faites par des entreprises. Chacune de ces réalisations
demande environ 100 à 130 h de travail encadrées ou non, réparties sur 15 semaines.

Ulteriorément, les étudiants qui le désirent peuvent effectuer d'autres U.V. de type projet: les U.V. 'Travaux de laboratoire'. Ces unités de valeur ont pour objectif essentiel de faire participer et d'initier les étudiants à des travaux de recherche effectués dans l'Université. En effet, il ne nous semble pas qu'il soit nécessaire pour commencer une recherche d'avoir fini d'accumuler des connaissances mais plutôt qu'il est nécessaire d'apprendre lorsqu'on ne sait pas. Le travail qu'aura à effectuer l'étudiant est, dans une certaine mesure, précisé en début de semestre par les enseignants qui l'encadreront. Un jury, au début de chaque semestre, vérifie que les travaux proposés sont bien conformes à ce que l'on peut et doit attendre de l'étudiant. En fin de semestre, le travail est évalué en tenant compte du travail réalisé, d'un rapport écrit et d'un exposé oral. Ce type d'U.V. nous apparaît comme très intéressant car il permet vraiment de 'déscolariser' les étudiants, de développer leur personnalité, leur imagination, leur ouverture à la nouveauté mais aussi au travail en équipe, de leur montrer que la recherche, l'innovation sont avant tout interdisciplinaires. Il leur permet de travailler sur des appareillages modernes de recherche sur lesquels il ne serait pas possible de faire effectuer des travaux pratiques. Chaque semestre, les sujets sont nombreux, environ 150 à 200 étudiants effectuent chaque semestre une telle U.V.

2. UN ENSEIGNEMENT EN ALTERNANCE

On ne soulignera jamais assez le rôle important que jouent les stages et projets en milieu industriel sur le développement des capacités innovatrices des étudiants et le rôle que peuvent jouer les étudiants eux-mêmes en stage notamment envers les petites et moyennes industries.

L'Université, sans développer un enseignement en alternance comme celui qui est organisé dans certains établissements, a toutefois institué plusieurs périodes de stages ou projets en milieu industriel.

Le premier, d'une durée d'un mois, a lieu au cours de la première année, un semestre après l'entrée à l'Université. Le stage a pour objectif de donner à l'étudiant une première expérience professionnelle. La nature de ces stages est très variée mais correspond dans la mesure du possible à des emplois ouvriers. À l'issue de ce stage, l'étudiant doit faire un court rapport écrit qui situe la tâche effectuée dans son environnement et dégage une réflexion personnelle.

Le stage 'ouvrier' est pour beaucoup le premier vrai contact avec la réalité du monde du travail.

Au cours de la deuxième année, les étudiants peuvent effectuer un deuxième stage, à l'étranger cette fois, afin de se familiariser avec la culture, les conditions de vie du pays et d'en pratiquer la
A côté de ces deux stages très limités dans le temps, l'ingénieur U.T.C. aura effectué au cours de ses études deux périodes de travail en milieu professionnel, chacune d'une durée de 6 mois. La première doit développer le savoir-faire des étudiants et leur permettre d'appliquer leurs connaissances toutes fraîches à la résolution de problèmes concrets. La deuxième période, placée en dernier semestre de formation consiste en un projet de fin d'études. Point final de la formation d'ingénieur, elle ouvre l'étudiant à la vie professionnelle. Il faut noter que la durée de ces deux dernières périodes permet une bonne intégration de l'étudiant dans l'entreprise et incite celle-ci à confier un travail bien précis à l'étudiant, dont elle peut escompter des retombées utiles.

Ces stages et projets sont jugés à partir d'une fiche d'évaluation de l'employeur qui donne son avis sur la personnalité de l'étudiant, la manière dont il a rempli les fonctions qui lui étaient assignées, etc., d'un rapport technique écrit et d'un exposé oral très limité en temps (10 à 15 mn).

La formation personnelle acquise par l'étudiant au cours de ces périodes est, bien sûr, considérable. Elles lui permettent de prendre en compte les réalités de l'entreprise mais également de mieux intégrer les enseignements qu'il a suivis ou suivra. A côté de cette formation personnelle, il faut noter l'influence importante de ces périodes sur l'enseignement. En effet, l'étudiant ramène à l'Université l'ambiance et les problèmes des industries. Sa pression discrète sur le corps professoral invite à un réexamen continu de l'enseignement, alimente la réflexion des professeurs et par là, contribue sans aucun doute à l'évolution de l'enseignement. Il est évident par ailleurs, que la définition des stages, leur suivi par des enseignants permettent de tisser des liens importants avec l'industrie. Notons enfin pour terminer que le projet est souvent l'occasion pour une entreprise d'aborder un problème nouveau dont les exigences du quotidien ne lui auraient pas permis de se préoccuper. L'étudiant en projet se doit alors de 'débroussailler' le sujet, savoir poser le problème et non plus résoudre ceux posés par les autres. Un esprit d'indépendance, d'autonomie est alors nécessaire, une méthodologie doit être acquise.

3. FORMER À LA CRÉATION D'ENTREPRISE?

Proposer à des élèves-ingénieurs un enseignement de 'création d'entreprise' ne nous a pas semblé réaliste: en cours et a fortiori en début d'études, ils ne se posent pas les problèmes en ces termes. Nous envisageons, par contre, de développer prochainement un tel 'enseignement' s'adressant soit à de jeunes diplômés, soit à des ingénieurs en fonction mais, dans l'un et l'autre cas, porteurs d'un projet réel déjà quelque peu réfléchi qu'il s'agirait de les aider à mettre sur pied.
Pour les élèves-ingénieurs, nous avons créé une 'initiation à la vie de l'entreprise' dont la forme et les modalités pédagogiques visent toutefois à leur donner le goût d'entreprendre. L'initiation se fait à travers la création ex-nihilo d'une entreprise fictive. Les étudiants, par petits groupes, définissent un produit ou un procédé autour desquels ils vont bâtir 'leur' entreprise.

Ils seront tout naturellement amenés à s'interroger :

a. Sur le marché, la concurrence.
b. Sur la production et la distribution.
c. Sur le financement.
d. Sur la forme juridique.
e. Sur les problèmes de personnel (embauche, qualification, salaire ...).

Ils seront amenés à monter un dossier, déjà solide et élaboré. À partir d'un certain nombre d'hypothèses construites avec les enseignants, ils feront évoluer leur entreprise et apprécieront sa viabilité. Il s'agit là d'une méthode relativement originale qui demande aux enseignants beaucoup de travail de suivi puisque chaque entreprise ainsi imaginée est un cas particulier qui évolue de façon spécifique. Nous n'avons pas voulu utiliser ou construire un jeu d'entreprise automatisé, reporsant sur une simulation et un modèle, car celui-ci enferme les étudiants dans une conception donnée de l'entreprise et dans des contraintes qui oblitérent l'imagination et la créativité.

Il s'agit pour nous, de permettre à de jeunes étudiants sans formation aucune en techniques de gestion, d'avoir rapidement une vision globale et dynamique d'une entreprise, vision dans laquelle ils s'investissent quelque peu puisqu'ils sont créateurs et acteurs.

Naturellement cette initiation est prolongée par un apport de connaissances (économie, finances, organisation et relations de travail, environnement de l'entreprise) utilisant largement la méthode des cas et la participation active des étudiants, sans perdre de vue :

a. Qu'il s'agit de former des ingénieurs et non des spécialistes...
b. Qu'il s'agit avant tout de lever des blocages d'ordre psychologique.

En effet ce sont souvent de tels blocages devant les techniques de gestion, plus que la méconnaissance de celles-ci, qui empêchent les ingénieurs de se lancer plus souvent dans la création de leur propre entreprise, ou d'apprécier tous les paramètres d'une innovation, du développement d'une idée originale.

Dans cette perspective, nous avons développé des U.V. dites de 'communication' dont l'objectif fondamental est de permettre à l'étudiant de mieux se situer par rapport à lui-même et par rapport aux autres. Dans ce cadre, sont vues les méthodes usuelles de créativité, telles que le brain storming et toutes les techniques fondées
sur la rupture des habitudes mentales et la combinatoire. A cela s'ajoute, au travers de différentes U.V. l'initiation ou la formation à des techniques relevant du marketing, de l'analyse de la valeur, de l'approche systémique appliquée aux organisations. Ajoutons au passage que l'enseignement des langues concourt à cette action en s'appuyant sur des pédagogies nouvelles (utilisation de documents authentiques, apprentissage en semi-autonomie ...).

4. LE RÔLE DE L'INFORMATION

On ne peut quitter ce domaine sans évoquer le rôle, aujourd'hui fondamental, de l'information scientifique, technique et professionnelle comme facteur d'innovation et d'évolution des entreprises.

On sait que les entreprises n'accordent pas une valeur suffisante à l'information. On sait que les Pouvoirs Publics s'en inquiètent et développent des mesures d'incitation, surtout à l'intention des P.M.I.

Nous pensons que les étudiants d'aujourd'hui, ingénieurs de demain, pourront faire évoluer les mentalités si au cours de leurs études, ils ont eux-mêmes pris l'habitude de recourir à l'information, que ce soit:

a. Par la consultation de la presse, non seulement scientifique mais également technique et professionnelle.

b. Par la consultation de systèmes documentaires et de banques de données.

c. Par l'aptitude à constituer des dossiers documentés sur des sujets précis.

Nous n'avons pas estimé souhaitable de regrouper ces différents aspects dans un enseignement spécifique mais plutôt d'inciter les enseignements à les introduire dans certaines U.V.:

a. Dans des U.V. de Culture Générale, en ce qui concerne la consultation de la presse et l'élaboration de dossiers.

b. Dans des U.V. Technique et Méthode, en ce qui concerne les différentes consultations évoquées, notamment la consultation de banques de données. Nous bénéficions à l'U.T.C. de Compiègne-Télédoc qui permet, avec assistance et conseil de spécialistes, d'interroger de nombreux fichiers. Compiègne-Télédoc est accessible aux enseignants, aux étudiants comme aux industriels de la région.
Il s'agit donc d'un ensemble complexe dont les qualités principales nous semblent être la souplesse, l'ouverture et l'adaptabilité.

Naturellement, un tel dispositif fluctue sans cesse à la recherche d'une optimisation globale issue de l'optimisation intrinsèque de chacune de ces composantes.

Mais l'ensemble reste cohérent et efficace et la meilleure garantie de cohérence et d'efficacité provient de la recherche d'une adéquation particulière de chacune des composantes à l'image que l'Université de Technologie s'est forgée, à l'origine comme un projet, selon un propos délibéré; image aujourd'hui confirmée par le succès qu'elle rencontre tant au niveau de l'enseignement que de la recherche.
ABSTRACT

This paper describes a course in product development for students in their fourth year of study for an M.Sc. degree in mechanical engineering at Chalmers University of Technology, Sweden. The course was developed and is conducted as a joint undertaking by the Department of Machine Elements and the Department of Industrial Management. A main feature of the course is the project work done by small groups of students working on new product ideas coming from industry, independent inventors, university personnel, and sometimes from the students themselves. The project work is to cover the whole innovation process and to result in a business development plan for the new product as well as a first prototype, when possible. The amount of calendar time and course work involved makes the project work comparable to a small feasibility study of a new product idea, as carried out in industry. There is no pre-defined solution, and the emphasis is placed on creativity, initiative, and the gathering of field information (state-of-the-art, patents, market survey, sources of finance etc). In addition, students are trained to make good presentations for managers, since a lack of communication skills often is a barrier to innovation in an engineer's work. The students also take a creativity test and participate in a business-idea contest. Running in parallel with the project work is a series of lectures with a direct linkage to the various phases and problems involved in the innovation process, as these occur during the course of the project work.

The course has so far been given four times. The selection of new product ideas with at the most a medium level of technical sophistication has been found to be important, preferably products with which the students have a user acquaintance such as accessories for cars and boats, sporting goods, and home appliances. Examples of past project ideas include a pancake maker, an energy-saving shutter, and automated fishing-tackle. Moreover, tutoring of the project work is crucial in several respects, such as providing realism during the work, motivating the group to act in case of genuine uncertainty, and securing that the work is not getting overly biased towards technical details.
Ce papier est une représentation du cours du développement de produits pour les étudiants qui en quatrième année d'études en vue d'une licence technique, à l'Ecole Polytechnique de Chalmers de Suède. Le cours a été organisé comme une collaboration entre l'Institut d'Eléments de Machines et l'Institut de l'Organisation Industrielle. Une grande partie du cours consiste en réalisation de projets, par de petits groupes d'étudiants que s'occupent de nouvelles idées de produits venant de l'industrie, des inventeurs indépendants du personnel de l'université et, quelquefois, des étudiants eux-mêmes. Le travail de projets est destiné à surveiller tout le procédé d'innovation et, aussi, à avoir pour résultat un plan de développement du commerce du nouveau produit, aussi bien qu'un prototype, si possible.

Le sens du cours, c'est, entre autres choses, d'étudier la possibilité de réussite d'un nouveau produit, introduit dans l'industrie. Il n'y en a pas de solution fixée d'avance et, on insiste sur la créativité et l'initiative. On prend aussi des renseignements sur la domaine (l'état actuel de la recherche, un aperçu du marché de brevets, les sources financières etc.). En outre, les étudiants apprennent à faire de bonnes représentations de directeurs, comme le manque de connaissance de communication souvent est l'obstacle de l'innovation dans le travail d'un ingénieur. Les étudiants passent aussi une épreuve de créativité et participent à un concours d'idées d'affaires. Parallèlement à la réalisation des projets, se passe une série de leçons où l'on étudie les phases et les problèmes du procédé d'innovation.

Jusqu'aujourd'hui, le cours a été donné quatre fois. La sélection de nouvelles idées de produits pour le moins passibles, quant au niveau technique, s'est montrée importante, surtout dans le cas où les étudiants en qualité de consommateurs connaissent les produits, par exemple des pièces de rechange de voitures et de bateaux, des articles de sport et des appareils électroménagers. "Un appareil à crêpes", un volet qui épargne l'énergie, des engins de pêche, voilà quelques exemples des dernières idées. Instruire du travail des projets, c'est très important, car en travaillant, les étudiants ressentent la réalité et, on les motive, en cas de pure incertitude, afin que le travail ne soit pas borné aux détails techniques.

ZUSAMMENFASSUNG

Das Folgende ist eine kurze Beschreibung eines Kurses in Produktentwicklung für Studenten an Chalmers Technische Hochschule, Schweden. Der Kurs wendet sich an Studenten die sich in vierten Jahr ihrer Ausbildung zum Diplomingenieur in Maschinenbau befinden. Für Planung und Leitung des Kurses sind das Institut für Maschinen- elemente und das Institut für Betriebswirtschaft gemeinsam verant-
1. DESCRIPTION OF THE COURSE

A problem in innovation and business development is how to integrate the different specialized skills, which are needed. A related educational problem is whether particular courses should be organized in order to contribute to this integration through increasing the versatality of an engineer. The purpose of this paper is to give a description of and relevant experience from a course in product development given at Chalmers University of Technology, Sweden. The course is first briefly described:

Title of the course: Product Development.

Purpose of the course: To give engineering students an integrated understanding of the different technical, economic and behavioral aspects of the innovation process and to train them in preparing a business development plan for a particular technology-based business idea.
Students: The course is open to students in their fourth year of study for a M.Sc., primarily in mechanical engineering. The course is not compulsory.

Management of the course: The course is given jointly by the Dep't of Machine Elements and the Dep't of Industrial Management.

Organization of the course: A main feature of the course is the project work carried out by small groups of students working on actual ideas for new or improved products. The groups may not be larger than five students and should be composed of students with different specialities within the M.Sc. curriculum. The ideas for new products may come from industry, independent inventors, university personnel, and sometimes from the students themselves. The project work is to cover the different aspects of the whole innovation process and to result in a business development plan for the new product as well as a first prototype, when possible. Points to be considered in the business development plan are in general:

- R&D (technical specification, need for further development, patents, variants, state-of-the-art, technological forecasts, etc.).
- Production (technology, organization, etc.).
- Marketing (segmentation, market shares, market growth, means of competition, analysis of competing products, need for further market analysis, etc.).
- Economy (discounted cash-flow analysis for different alternatives, rates of return, financing, etc.).

The amount of calendar time (six weeks) and work time per project group (roughly seven-man-weeks in all) makes the project work comparable to a feasibility study of a new product idea, as carried out in industry.

The project work is divided into three phases. Each of the first two phases ends with a meeting designed as a meeting with a steering committee for the project. Alternatives and suggestion are then presented and decisions about how to proceed are taken by the students and the tutors of the projects. A written progress report is required at each of these meetings, and each member of the project group should be prepared to make an oral presentation. Members of other project groups are assigned the roles of general manager, technical manager, and marketing manager in a steering committee. The third and final phase ends with a full presentation of the business development plan. This should also be documented in a final report.

The work content of the different phases varies according to the type of business idea, but commonly the phases contain the following elements:

Phase 1: Preliminary market analysis
Preliminary technical analysis

Phase 2: Product design

Phase 3: Market survey
Preparation of business development plan
A series of lectures runs in parallel with the project work with a direct linkage to the elements in the different phases. These lectures are also intended to cover aspects of innovative work which cannot be illustrated in the project work, such as product development work in large companies. The following lectures are given:

1. Introduction. The innovation process
2. Behavioral aspects of working in project groups
3. Creativity and idea generation
4. Need analysis and market surveys
5. Project organization and planning
6. Evaluation of ideas and projects
7. Economic analysis
8. Patents
9. Systematic design
10. Licensing
11. Marketing
12. Presentation techniques
13. Guest lecturers from companies

Finally the course starts with a business idea contest and a creativity test.

Examination: The grades are primarily based on the result of the project work. In this work, there is no pre-defined solution, and the emphasis is placed on creativity, initiative, and the gathering of relevant field information (state-of-the-art, patents, market data, sources of finance, etc.). The comprehensiveness and realism of the business development plan is decisive. This means that it is also legitimate to propose the termination of a project as a result of a feasibility study.

In addition, students are trained to make good presentations for managers, since a lack of communication skills often is a barrier to innovation in an engineer's work. Finally, an individual oral examination may modify the grade given on the project work.

2. RESULTS

The course has so far (1982) been given four times, and it is still a little early to assess its proper organization and value. Naturally, it is difficult to apply absolute evaluation criteria. The course is too short to result in patent applications, innovations, and new companies. A few project groups have continued after the course with grant applications or work on a Master's thesis, but in general students exit the innovation process after the course examination.

Since the course is non-compulsory, the 'market demand' for it is one indicator of its value. In these terms the course could be considered a success. In three years it became the most popular course with over seventy applicants. Each student submits a written, confidential evaluation after the course, and these evalua-
tions also indicate that the course is a successful one.

Several factors may account for this. The whole subject of product development and innovation has gained recent popularity; also, a new course raises curiosity. However, the character of the project work is probably the major factor behind the success of the course.

A basic question in educating engineers for innovative and entrepreneurial activity is whether one should attempt to integrate the different aspects of the whole innovation process within the context of a single course of normal proportions. According to the experience gained from our course, such an integrated approach has potential value. Certainly arguments for an integrated course could be based on the positive student reactions and teaching experience, but nothing is thereby directly said about the value of such a course in relation to real working conditions in industry. No data are available at this moment for an assessment of this value. However, experience from managing innovation in industry points to the benefits of using integrative approaches such as venture organizations. A basic characteristic of a venture organization is the vesting of responsibility for all aspects of the development and marketing of a new product in a small venture group. A venture organization also differs from a normal project organization in that individuals usually are assigned only to one venture group at a time. (See von Hippel 1977, Hlavacek and Thompson 1973 and Rothwell for further descriptions.) Thus, also in light of the analogy with this latter experience an integrative approach in course work seems justified.

However, there are two crucial factors in achieving integration in the course:

- The inter-departmental approach
- The work on new product ideas under realistic conditions

Inter-departmental cooperation within a university may involve difficulties. In addition to any personal conflicts and resource conflicts, each department tends to develop a subculture of its own. The aggravations of conflicts could be suppressed by a strong university management, but overcoming subcultural differences in language, attitudes, problem-solving behavior etc. requires much time, internal communication, and socializing efforts. Especially these differences are large between a technical oriented department and a department for industrial management, industrial economy, and the like. What in retrospect appears to be instrumental is the creation of a well-integrated course management team of young persons from the cooperating departments, who could adopt the role of generalists and act as tutors in the project work.

Regarding the work on new product ideas, a great deal of experience has been gathered so far. First, student project (or rather venture) groups should be assigned to product ideas carefully selected in advance by the course-management team. Only in case of
capable and interested venture-groups, the idea generation and selection phase could be left to them.

Second, the selection of product ideas, which can give realism to the work under the given limitations is essential. A suitable product idea should have at the most a medium level of technical sophistication to prevent technical bias in the work. The students should preferably have a user acquaintance with the idea in order to save time. One could use ideas of the 'technology-push'-type as well as the 'demand pull'-type in the course portfolio of ideas in order to illustrate the differences in approach. It is often easier to inspire students to work on an idea for an entirely new product than for an improvement of an existing product, which has been refined by others. Techno-economic aspects of production are difficult to probe within the scope of a feasibility study.

It is worthwhile to create a 'bank' of suitable product ideas and try to establish connection with sources of actual ideas in industry, in government institutes, among investors and among university personnel. Secrecy problems are often surmountable, and it is highly valuable to have the tutorial assistance of a person with a practical interest in the particular idea.

Among the more than 30 past product ideas, which turned out to be suitable were a pancake maker, an energy-saving shutter, and an automated fishing-tackle. Less suitable were a robot wrist and a pneumatic tape-reader.

Third, motivated tutors with an ability to motivate and with an integrated knowledge of innovation constitute a critical resource. Since it has been found important to limit the venture group size to five students, a lack of experienced tutors may arise, at least in the first few years the course is given; it is essential but difficult to motivate students to work as if the problems were real and to create a climate in the project work, which gives the students a grasp of the many intangible aspects of product development, not the least behavioral ones. For example, it is difficult to motivate students to deal with genuine uncertainty and to make them decision-oriented. They may also lack the ability to work in groups.

Finally, it appears that the present amount of work time, and especially calendar time, of the course is somewhat too small for a feasibility study with a reasonable coverage, even for a simple product idea. To some extent it is possible to adapt to time constraints by sacrificing depth and/or by choosing suitable stages at which the venture group enters and exits from the innovation process. However, there are limits to this possibility, for example, because of the time needed to gain access to patent information or market data.

Naturally, there are limitations to a course like this one, some of which are self-evident. It is difficult to simulate the conditions of product development in high-technology and/or large companies. On the other hand, it may be argued that one should not within a university try to provide such education through 'doing while learning', education which is better provided by industry.
through 'learning by doing'. It is also conceivable that industry will in the future for several reasons internalize activities such as R&D and advanced education to a higher relative degree. A proper role differentiation between industrial education and university education must be considered. Perhaps, in the area of innovation and entrepreneurship the teachability in university setting is especially limited (See Singh 1971 for a review of standpoints on this issue in various countries).

In concluding, the possibility should also be mentioned that an integrated university course in product development could provide a source of real ventures, although the probability of real venture success may be comparatively low. Such course activities could be linked to a kind of venture development unit or innovation center attached to the university.

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ABSTRACT

Is it necessary to improve engineering education with respect to innovation and entrepreneurship? A survey carried out amongst young engineers and their employers proved that this is really urgent. We plan to approach the goal in three ways: First we shall include the fundamentals in all engineering courses. Second we shall offer options. Third we shall establish postgraduate courses. The student must be led not only to knowledge but to action. Therefore the structures and methods of teaching must be adapted; we try to develop such methods.

RESUME

Est-ce qu'il est nécessaire d'améliorer la formation de l'ingénieur dans la direction de l'innovation et de la gestion? Une étude entreprise parmi un nombre de jeunes ingénieurs et leurs patrons a affirmé la question. Nous voulons approcher le but en trois manières: 1. Approfondir ces disciplines pendant la formation de base de tous les ingénieurs. 2. Offrir des cours à option. 3. Perfectionner les capacités dans des cours 'post-diplôme'. Il s'agit d'une formation envers l'action et non seulement de l'enseignement de connaissances. Il est donc nécessaire d'appliquer des méthodes de formation appropriées; nous sommes en train de développer ces méthodes.

ZUSAMMENFASSUNG

1. KENNZEICHEN DER SCHWEIZ. INGENIEURAUSBILDUNG

In den letzten Jahren hat sich die Ingenieurausbildung in den meisten europäischen Ländern gewandelt. Zum besseren Verständnis der nachfolgenden Darlegungen sei deshalb auf die Besonderheiten der Schweiz. Entwicklung hingewiesen:

Erstens streben wir in der Schweiz nicht nach einem Einheitsingenieur. Industrie und Wirtschaft brauchen verschiedenartig ausgebildete Ingenieure; deshalb haben wir die zwei alternativen Ausbildungswege des mehr theoretiebezogenen ETH-Ingenieurs und des mehr anwendungsbezogenen HTL-Ingenieurs bewahrt. Die Gleichschaltung der beiden Typen, wie sie etwa in der Bundesrepublik Deutschland zwischen Fachhochschulen und wissenschaftlichen Hochschulen angestrebt wird, hat in der Schweiz nicht Fuß gefasst. Wegleitend ist für uns das sehr breite Einsatzspektrum des Ingenieurs, das vom Forscher über den Konstrukteur und den Fertigungsingenieur bis zum Verkaufsingenieur reicht.

Zweitens sind wir im Vergleich zum Ausland in der glücklichen Lage, dass die Ingenieurschulen ein hohes Mass an Autonomie genießen, wobei der Staat praktisch nur auf dem Weg über das Budget richtungsweisend wirkt. Bei uns ist die Verbindung zum Staat eher locker, die Verbindung zur Industrie hingegen eher eng.

2. IST DIE MODERNISIERUNG DER STUDIENPLÄNE IN RICHTUNG INNOVATION UND UNTERNEHMENSFÜHRUNG NOTWENDIG?

Die Schweiz ist ein kleines Land ohne Rohstoffen, trotzdem hoch industrialisiert; mehr als ein Drittel der Bevölkerung lebt vom Export. Die Ingenieure tragen wesentlich zur guten Konkurrenzfähigkeit unserer Industrieprodukte bei. Seit jeher pflegten wir die Erziehung zum innovativen und unternehmerischen Handeln; die rasante Entwicklung neuer Technologien hat jedoch Zweifel aufkommen lassen, ob das Bisherige noch genügt.


Wenn wir die Ergebnisse den zwei Stichworten im Titel dieses Aufsatzes zuordnen, so stellen wir folgendes fest.

**Innovative Qualifikationen:** Untererfüllt sind die Befähigung zur Teamarbeit sowie die Fähigkeit, unter Zeitdruck brauchbare, aber nicht ideale Lösungen (sogenannte 90%-Lösungen) zu erarbeiten. Ubererfüllt sind hingegen die Spezialisierung in einem Fachgebiet und die ausgesprochenen Kenntnisse als Theoretiker.

**Unternehmerische Qualifikationen:** Untererfüllt sind die Kenntnisse in Organisationslehre, Führungstechnik, Betriebspsychologie und Personalführung.
Die SCOPE-Studie hat nur ETH-Ingenieure erfasst; nach Ansicht des Verfassers lässt sie sich jedoch mindestens teilweise auch auf HTL-Ingenieure übertragen.

Es drängt sich jetzt die Frage auf, ob die für Innovation und Unternehmensführung notwendige Breite und Tiefe bereits in der Erstausbildung anzustreben sei, oder ob die anspruchsvolle Stufe erst nach einigen Jahren Praxis an eine Elite vermittelt werden soll.

3. SCHULPOLITISCHE ENTSCHEIDUNGEN

Folgende drei Möglichkeiten bieten sich an: Man kann die neuen Anforderungen:

a) Zusätzlich vermitteln, indem das Normalstudium verlängert wird;
b) Ins Normalstudium einbauen, indem man andere Stoffgebiete weglässt;
c) Als Nachdiplomstudium anhängen.

Die Variante a), nämlich die Verlängerung des Normalstudiums, ist in der Schweiz wohl diskutiert, aber dann abgelehnt worden. Unsere Studenten werden bis zum Diplom eher älter als ihre ausländischen Kollegen; eine weitere Verlängerung der Studienzeit ist deshalb nicht angezeigt. Hingegen wollen wir die Varianten b) und c) verwirklichen.

Variante b): Einbau ins Normalstudium.


In der Schweiz bestehen aber auch Normalstudiengänge im Betriebsingenieurwesen. An der ETH Zürich kann man sich in 8 Semestern und an der HTL Muttenz in 6 Semestern zum Betriebsingenieur ausbilden lassen. Beide Studiengänge stellen Wahlmöglichkeiten im Rahmen der Abt. Maschinenbau dar. Die ETH zielt eher den oberen Führungsbereich (Unternehmensebene), die HTL eher den mittleren, technischen Führungsbereich (Betriebsebene) an.

Variante c): Nachdiplomstudium.

An unserer Ingenieurschule führen wir ab Herbst 1982 ein Nach-
diplomstudium in Energienutzungstechnik. Dass der Energieingenieur als Fachmann notwendig ist, braucht heute nicht besonders betont zu werden. Im Innovationsbereich eröffnen sich mit der Energie sparentechnologie gute Chancen für kleinere und mittlere Firmen, neue oder verbesserte Produkte zu entwickeln, z.B. auf dem Gebiet der Wärmepumpe, der Wärmekraftkopplung, der Sonnenkollektoren oder im Bereich der Haustechnik.

Der Mangel an technischen Fachleuten mit betriebswissenschaftlicher Ausbildung hat in den letzten Jahren zur Eröffnung weiterer Nachdiplomkurse geführt. Sie stehen Absolventen aller Ingenieurfachrichtungen offen. So kann man ein Nachdiplomstudium in Betriebsführung an der ETH Zürich sowie an 4 Ingenieurschulen HTL absolvieren.


4. DIE FÖRDERUNG DER INNOVATIVEN FÄHIGKEITEN


Im 6. Semester führen wir die interdisziplinären Teamübungen durch, bei denen 6 Studenten der Disziplinen Verfahrenstechnik,
Chemie und Elektrotechnik gemeinsam ein komplexes Problem aus der Praxis bearbeiten. Hier zeigt es sich, ob der Student zumindest die Sprache seiner Kollegen gelernt hat, ohne die eine gemeinsame Bewältigung der Aufgabe nicht möglich ist.

Wir müssen die Grenzen im Auge behalten, Unsere Studenten werden nicht zu Innovationsspezialisten ausgebildet, aber ihr Sensorium für Innovation wird bewusst gefördert. Der Student soll die Fähigkeit erwerben, ein interdisziplinäres Team zu leiten und die Spezialisten zu koordinieren. Es geht bei diesen Bestrebungen weniger um die Schaffung neuer Technologien, als vielmehr um die sogenannte Technologiediffusion, d.h. die Verbreitung neuer Technologien und die Umsetzung in marktgängige Produkte.

Die Förderung der innovativen Fähigkeiten stellt viele Dozenten ein schwieriges Anliegen dar. Sie selbst sind ja seinerzeit auf konventionelle Weise ausgebildet worden, wobei das Tatsachenwissen im Vordergrund stand. Dozenten-Einführungskurse in die neue Methodik sind deshalb angezeigt. Gegenwärtig führen wir einen Dozentenkurs über die Methodik der Gruppenarbeit durch.


- Die ETH bearbeitet eher Grundlagenprobleme und komplexe Projekte für größere und mittlere Firmen.
- Die HTL übernimmt eher Entwicklungsarbeiten an einzelnen Produkten für kleine und mittlere Firmen.

Die Studenten arbeiten oft an solchen Innovationsprojekten mit.

5. DIE FÖRDERUNG DER UNTERNEHMERISCHEN FÄHIGKEITEN


b) Normalstudium zum Betriebsingenieur. Die in der SCOPE-Studie


Leistungsbewertung, Notengebung und Prüfung müssen mit der Unterrichtsmethodik übereinstimmen. Wenn der Unterricht affektive Lernziele setzt, so müssen diese ebenfalls geprüft werden, was natürlich schwieriger ist als die Prüfung kognitiver Fähigkeiten. Als Beispiel nenne ich die Fähigkeit, unter Zeitdruck sogenannte '90%-Lösungen' (siehe Abschnitt 2) zu erarbeiten. Solche Lernziele sind notwendig, damit der Student über Innovation und Betriebsführung nicht nur Bescheid weiß, sondern auch entsprechend zu handeln lernt.

6. AUSBlick

Ich habe Innovation und Unternehmensführung in 2 getrennten Kapiteln behandelt; tatsächlich sind sie jedoch voneinander abhängig: Die vermehrte Innovationsanstrengung hat eine direkte Auswirkung auf die vermehrte unternehmerische Ausrichtung der Ingenieure. Innovationen sind ja nicht an sich schon gewinnbringend, sondern erst dann, wenn sie zu marktgängigen Produkten geworden sind. Innovationsberater müssen deshalb gute Kenntnisse aus der Unternehmensführung besitzen, damit sich innovative Ideen rasch und zweckmäßig verwirklichen lassen (Transferprozess).

Ich habe Ausbildungsveranstaltungen dargestellt, die entweder
bereits realisiert oder zumindest heute schon absehbar sind. Weitere Schritte werden in den nächsten Jahren folgen. Das ist notwendig, wenn die Schweiz ihren hohen technologischen Stand im Kreise der führenden Industrienationen bewahren will.
Anhang: Identitätsprofil neuausgebildeter ETH-Ingenieure.

- Anforderungen / Fähigkeiten

Grundsätzliche Kenntnisse in vielen Fächern
Spezialisierung in einem Fachgebiet
Kenntnisse von Fremdsprachen
Rechnungswesen
Operations Research und Optimierungen
Betriebspsychologie und Personalführung
Organisationslehre und Führungstechnik
Marketingkenntnisse
Breite Allgemeinbildung auch im nicht fachlichen Bereich
Allg. EDV-Wissen über die Einsatzmöglichkeiten der EDV
Ausgesprochene Eigenschaften als Theoretiker
Ausgesprochene Eigenschaften als Praktiker
Fähigkeit unter Zeitdruck brauchbare aber nicht ideale Lösungen zu erarbeiten
Verantwortungsgefühl für Umwelt und Gesellschaft in die Praxis umsetzen
Fähigkeit im Team zu arbeiten

Quelle:
JO, Nr. 10, 1981

Antworten (gewogenes Mittel) auf die Fragen: Anforderungen der Praxis (Profil A) bzw. Von der Hochschule mitgebrachte Kenntnisse und Fähigkeiten (Profil B). Die Antworten wurden wie folgt gewertet: 1 = sehr; 2 = ziemlich; 3 = ein wenig; 4 = gar nicht.
DESIGN PROJECTS IN THE CURRICULUM OF THE DEPARTMENT OF INDUSTRIAL DESIGN ENGINEERING OF THE DELFT UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Design projects are the core of the curriculum of the Department of Industrial Design in Delft. In the structure of the design course certain methodological views are reflected. Design is an iterative problemsolving process in which reductive and deductive reasoning take turns. Therefore projects should offer room for intuition and creativity. Development projects require a concentric phasing, in order to identify futile solutions as early as possible. In the first year the design process is introduced by prestructured projects, focussing on certain steps of the design process. In subsequent years the complexity of the projects is increased by adding more aspects to the design problems and covering more phases of the product development process.

RESUME

Les projets de design constituent l'essentiel du cours de l'Ecole de Design Industriel à Delft. Certaines conceptions méthodologiques se reflètent dans la structure du cours de design. Le design est un processus iteratif dans lequel des raisonnements réductif et déductif se succèdent. Pour cette raison il est nécessaire que les projets laissent place à l'intuition et la créativité. Les projets doivent être divisé en phases concentriques afin de pouvoir identifier au plus vite les solutions sans valeur. En première année les processus de design est introduit au moyen de projets préstructurés qui attirent l'attention sur certaines phases du processus de design. Les années suivantes la complexité des projets est augmenté en ajoutant plusieurs aspects au problèmes de design et en traitant plusieurs phases du processus de développement de produit.

ZUSAMMENFASSUNG

Kern im Studiengang der Industrial-Design Abteilung, Delft sind die Design-Projekte. In de Lehrprogrammstruktur werden verschiedene methodologische Gesichtspunkte reflektiert. Design ist ein iteratives Problemlösungs-Prozess wo reductive und deduktive Argumentationen einander abwechseln. Deshalb sollen die Projekte raum für Intuition und Kreativität lassen. Entwicklungsprojekte brauchen eine konzen-

1. INTRODUCTION

The Department of Industrial Design Engineering offers a five year course in product design and product development, in which design is taken to be more than solving a mere technical problem. The curriculum covers therefore a wide range of subjects; theory lectures and exercises are offered by four subdepartments: Construction, Ergonomics, Formgiving and Innovation management. However, having a pure cognitive knowledge of all relevant subjects is insufficient for an adequate performance of the industrial design engineer on the job. Design students should be trained extensively in the application of theories, methods and facts from different disciplines to practical problems. Therefore in each of the five years of the curriculum an increasing amount of time is spend on design projects; from 200 hours in the first year up to 500 hours in the fourth year. Including the fifth year's master's thesis project about one fourth of the curriculum is devoted to design projects. Compared to other engineering design schools in the Netherlands this is a considerable amount of time.

2. DESIGN METHODOLOGY

To design educational design projects one needs conceptual models of the design problem and the design process. Design methodology offers these models. Before going into the details of the design courses it is worthwhile to state our main methodological views.

a. the Iterative Structure of Design

In order to fulfill its function a product must have certain properties. They depend on the spatial and physico-chemical form, however also the environment in which the product is used influences its performance. So the selected form of the products and its part gives a potential of properties, whereas only some of them are actualized by a particular way of use, resulting in a specific performance. The relationship between function and form is depicted in Fig. 1. Statements about the performance of a given product can be made by deduction, provided that detailed data about the rectangles on the left hand side of Fig. 1. are given. There is only one definite conclusion: The product performs as required or not. However the kernel of the design process is the reasoning from right to left. From hypothetical statements about the required performance
the designer has to infer categoric statements describing the form of the product and hypothetical ones prescribing its use. According to Eekels (1973) this reduction cannot be made by deduction, nor by induction. Here a creative moment is necessary. Moreover there is not one solution, there are numerous solutions.

As a result of this design problems can only be solved by an iterative problemsolving process in which analysis and synthesis (reduction), simulation (deduction), and evaluation (comparing predicted properties with required ones) take turns. Fig. 2. gives a fundamental model for the design process (Eekels et al., 1981); it shows the necessary steps and their logical relationships. Normally several
iterations are required, but even solving the smallest design problem requires at least one cycle. Therefore a well planned development process should provide room in every phase for each of these steps.

In the second year a course in design methodology is given. Apart from an introduction to the fundamentals of logic and the philosophy of technology, the course deals with the methodological problems of each step of Fig. 2. Although the course aims especially at a proper understanding of these problems, also the current methods and techniques are demonstrated and discussed, whereupon they can be put into practice in the design projects.

b. Concentric development.

In the course of design project one has to consider numerous factors such as function, construction, reliability, cost, market, potential, ergonomics, packaging, distribution, law, etc. A new product will be successful in so far as the corresponding requirements are met. It is known that only a small percentage of ideas for new products survive the development stage. Because of the severe cost of product development it is of paramount importance to identify the futile ideas as early as possible in the process. Of course at the start it is not known which problems an idea will bring and whether they can be solved at all. The best thing to do is executing the project in a number of phases, separated by decision points. In every phase all factors must be considered. The project starts with a broad survey, in successive phases, the study becomes more and more elaborate. Every phase may end in several working-outs of the output of previous phases, so a decision must be made as to which alternative will be further developed. Eventually a phase is repeated or the development process is terminated. We call this approach concentric development. It is one of the most important methodical principles for effective and efficient product development.

Broadly speaking the phasing of product development looks as in Fig. 3. Strict product development starts from a new product idea which is the result of the idea-finding phase on the basis of the corporate objectives and strategies (Eekels, 1981). Once a new product idea is identified the development process is teleological; the idea serves as a goal which can be kept in mind. Ideafinding has a much more heuristic nature, because one scarcely knows what is looked for.

3. THE STRUCTURE OF THE DESIGN PROJECT COURSE

The previously described methodology offers the basis for the structure of the training program by means of projects. The department decided in favour of the following framework. Starting in the first year with an introduction to the design process, the second and third year are devoted to strict product development projects, whereas a full scale product development project is executed in the fourth year. This will be illuminated in a more detailed description.

First year. The introduction to the design process starts with a
problem for which a simple product can be designed. Mostly the problem of litter collection and removal in a small community is used. The community and the specific situation are described in a short specification and the students are requested to design a product for this problem in a short period (about one day) and put together a rough scale model of the design. This results in a weird collection of roughly made cardboard litterbuns of great variation. Subsequently the students have to record the pursued process, which afterwards is evaluated together with the staff to make them realize that design is a process of defineable, describable steps.

Second year. Product design becomes more serious but is mainly directed to the functioning of products with regard to the users. This concerns handling and form. Projects start from a verbally stated new product idea and end with a more or less detailed sketch design. Integration of the first year theoretical subjects such as ergonomics and form studies is encouraged. Because products are selected that relate logically to these centres of attention, handling and ergonomics can be consumer-tested on a prototype, while shape, de-
tailing and colour are studied in various rendering techniques, 
dummies and scale models. The design of a surfboard carrier is a 
typical task in this year.

**Third year.** Strict product design continues in the third year, how­
ever with the addition of the business economics function which calls 
for focussing on materials, construction, production techniques and 
cost estimation as well as on user requirements. Also now the de­
tailed design phase is covered. Products become more complex and 
the demands on the integration of theory of former courses increase. 
Powertools as lawn mowers are popular items for projects.

**Fourth year.** A full product development project takes up all of the 
fourth year. In cooperation with an industrial company an idea 
finding project is executed leading to a number of new product ideas 
for this company. These initial proposals are further evolved in an 
explicitly planned strict development process ultimately resulting 
in detailed new product designs. Evidently this calls for thorough 
research and preparation by staff members. Locating a willing com­
pany is a time consuming and venturesome process, usually however 
these projects prove to be rewarding and stimulating for all par­
ties involved. Until now projects with a medium sized manufacturer 
of wooden furniture and a large aluminum processing company have 
been taken up.

4. ORGANIZATION

In each of the four years the study load of the curriculum amounts 
to approximately 1700 hours. About 200 hours are taken up for de­
sign projects in the first year, 250 in the second, 340 in the third 
and 500 in the fourth year. The first year is characterized by a 
number of relatively short projects in the first period followed by 
one project in the second half year. The second and third year both 
have two half year projects while only one project takes up all of 
the fourth year.

The number of students in the various years, ranging from 140 in the 
first year to about 80 in the fourth, makes working with groups of 
students inevitable. Optimal working conditions are attained with 
groups of up to five students which operate more or less without 
a leader but can with mutual consent appoint various tasks to each 
member. Ideally each group should be accompanied by two staff members 
but due to shortage in personnel this is often done by one who helps 
where necessary and sees that proper track and speed are maintained. 
Judging of results and awarding marks is done by more than one staff 
member per group on the basis of an itemized system that is known to 
the students in advance. This disadvantage of not exactly knowing 
the contribution of each individual student to the group result is 
outweighed by the advantages of crossfertilization and training 
in group cooperation.

Each year staff has about eight members coming from one of the four
subdepartments. The multidisciplinary staffs are responsible for preparation, compilation, description and evaluation of the design exercises. Each staff is directed by an appointed coordinator. Every year some members of different staffs change places to ensure versatility and maximum spinoff, however all this is done with a firm view on continuity.

5. CONCLUDING REMARKS

Having completed this course of design projects it appears that most students are able to perform satisfactory in real product developments in industry. In many master's thesis projects this has been demonstrated (Eekels, 1982 and Schierbeek, 1982), and most of our students find proper employment shortly after graduation. We believe this can be traced to the fact that the course enables the Industrial Design Engineer to handle complex and multidisciplinary problems in a methodical and systematic way.

REFERENCES


QUELQUES EXPÉRIENCES DE CRÉATIVITÉ TECHNIQUE AVEC LES ADOLESCENTS: UN INTRODUCTION AU VRAI MÉTIER DE L'INGÉNIEUR?

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ABSTRACT

The position of teachers and teenagers towards technological knowledge, as well as some attempts made in Europe to provide them with better information, are briefly outlined. The factors promoting an innovating mentality are analysed.

The second part of the survey describes the various experiments carried out in Belgium by TETRA H to encourage the teenagers in those attitudes. Their descriptions and illustrations continually emphasize the importance of tackling the problems with a mind open to both criticism and novelty.

As a conclusion, the teenagers are always eager to understand, to discuss and to create, provided they have leave to discover and to implement ideas by themselves.

RESUME

L'attitude des enseignants et des adolescents vis-à-vis des connaissances technologiques ainsi que quelques tentatives qui ont été faites en Europe pour les mieux informer, sont brièvement évoquées. Les facteurs qui sont à la base d'une attitude innovatrice sont analysés.

La deuxième partie présente les expériences successives effectuées en Belgique par TETRA H pour éveiller cette attitude chez les jeunes. Elles sont décrites et illustrées, en instanstant constamment sur l'importance d'aborder les problèmes traités de façon ouverte à la critique et à l'imagination.

En conclusion, le désir des adolescents de comprendre, de critiquer et de créer est toujours bien vivant s'il leur est offert d'inventer et de construire.

ZUSAMMENFASSUNG

Die Haltung der Lehrer und der Jugendlichen gegenüber den technologischen Kenntnissen, sowie einige Versuche in Europa, ihnen bessere Information zu übermitteln, werden hier im kurzen dargestellt. Weiter untersucht man die Faktoren die einer innovierenden Mentali-
tät zugrunde liegen.


Zum Schluss darf man sagen, dass bei den Jugendlichen immer der lebendiger Wunsch besteht, Sachen zu begreifen, zu beurteilen und zu erschaffen, vorausgesetzt dass man ihnen die Möglichkeit bietet, zu ersinnen und zu erbauen.

1. ATMOSPHÈRE DE LA FORMATION PRE-UNIVERSITAIRE

Sans entrer dans des considérations pédagogiques profondes, il est assez manifeste que l'ambiance dans laquelle se déroule la formation des jeunes avant l'entrée à l'université, est déterminante sur leur orientation. On s'est beaucoup inquiété, dans les années '70, de l'évolution de l'attitude publique envers la science et la technologie. En 1976, dans un texte repris par le New Scientist, le Prince Philip d'Edimbourg déclarait:

'... the very changes of the postwar years that we brought about in order to equalise opportunity and to reduce inequalities ... have also succeeded in changing attitudes to science and to education as a whole. Whether it be stories of the rat-race of business and industry, or whether it be the awareness of the dangers of industrial pollution and the complementary concern for conservation; whether it be the association of scientific research with nuclear weapons or the anxieties generated by the prospect of using nuclear energy; the fact remains that there is a dramatic swing away from science in schools and universities.'

Un certain nombre d'organismes étaient conscients de ce que cette tendance provenait en grande partie d'une méconnaissance des techniques, d'une absence d'information et, plus profondément, de l'inexistence d'une éducation technologique au sens le plus large. Ils ont réagi principalement en tentant d'intéresser les éducateurs: ainsi, ESSO en Allemagne reçut plus de 10.000 enseignants au cours de 300 séminaires organisés en 7 ans. Quelques entreprises françaises et belges ont agi de même. En Angleterre, on a vu naître, depuis dix ans, quantité de groupements cherchant à multiplier les contacts entre l'école et l'industrie. On a créé notamment, dès 1968, un 'Project Technology' visant à équiper les écoles afin d'introduire la connaissance technique dans le curriculum courant. Actuellement, Trent Polytechnic gère le 'National Centre for School Technology' qui est, non seulement, un centre de réflexion sur le sujet, mais
produit le matériel didactique utile aux écoles. Ceci n'est qu'une initiative parmi d'autres.

Tout cela représente un effort d'ouverture louable, mais il faudra plusieurs décennies pour qu'il soit fait un large usage de ces moyens avec imagination et de façon intégrée aux autres cours car, si les techniques ne sont plus tout à fait ignorées de certaines écoles, elles sont souvent - même dans le cas de projects, notion très à la mode actuellement - l'object d'une présentation figée et close: il y a LA solution donnée à un problème, solution à apprendre et reproduire.

Or ce que nous recherchons aujourd'hui, c'est le moyen d'encourager les jeunes les plus imaginatifs à entrer dans la profession d'ingénieur et à y rester créatifs et entrepreneurs. Dans un article récent auquel je renvoie le lecteur, G. Brown a très bien résumé ce qu'il faudrait faire pour que les jeunes les plus doués soient tentés d'entreprendre des études d'ingénieur. Je n'insisterai que sur un point: en ce qui concerne la créativité, si le programme des écoles secondaires évolue comme nous le souhaitons, il faudra profondément réexaminer, en tout cas en Belgique, les examens d'admission car, aujourd'hui, ils retiennent avant tout des mathématiciens à forte capacité de mémoire et non des étudiants entreprenants et créateurs.

2. LES BASES D'UNE ATTITUDE INNOVATRICE

Sans doute plus que les techniciens, les artistes se sont penchés sur le problème des sources de la création. Dans un ouvrage sur la créativité artistique, Marthe Seguin présente le schéma 1. Ce schéma met en évidence la complexité du réel, à travers notre activité mentale, permet de débloquer le désir de créer et les gestes correspondants. Je crois que les aspects 'perception, sensibilité, raisonnement', qui mettent notre affectivité en relation avec le monde extérieur, sont aussi essentiels en technique qu'en art. Le poids des méthodes rationnelles dans l'art de l'ingénieur lui fait trop oublier l'importance du rêve dans la création.

On parle beaucoup actuellement d'une 'vue systémique' des problèmes: ce sera particulièrement vrai pour qui se veut innovateur. Baez et Alles, dans une publication ancienne de l'Unesco, résumaient ainsi ce qui permettrait 'l'esprit de changement grâce à l'aptitude à concevoir':

1. Imaginer ce qui peut-être créé, la façon de le faire.
2. Prendre des décisions en situation d'incertitude, même si l'on risque de payer cher cette erreur.
3. Estimer si une nouveauté sera également chose utile.
4. Inventer des modèles de choses à faire.
5. Utiliser les principes scientifiques: la technologie, l'imagination pour réaliser de nouvelles structures remplissant des fonctions déterminées à l'avance.
Ils suggéraient d'inclure, dans un enseignement dit de science intégrée, des notions de conception tirées de la technologie et de l'ingénierie en respectant trois principes de base:

1. Curiosité, donc esprit de recherche, c'est-à-dire: savoir et comprendre.
2. Compassion, d'où engagement qui est lié à fraternité et responsabilité.
3. Compétence, soit aptitude à résoudre les problèmes qui même à prendre l'initiative de ces changements.

D'où en pratique ils aboutissaient, de manière très ouverte, à la notion de projects qui se doit de dépasser la réalité présente, faute de quoi on se contenterait de reproduire l'existant.

Cette structure par projet est à la base de nombreuses réalisations parmi les plus dynamiques. Elle se matérialise par exemple en Belgique à l'École Decroly où des équipes formées d'élèves d'âges très différents ont pu traiter ensemble un problème choisi par eux. En dehors de l'école, on a de nombreux exemples de réalisations techniques par des groupes de jeunes. Certains sont exceptionnellement innovateurs tels cet 'oscillating aerofoil to power a pump',

Schéma 1.
dont le prototype opérationnel avait été réalisé par un groupe scolaire, primé par la BBC (Young Scientists of the Year '76). Ces jeunes maîtrisaient parfaitement l'ensemble de leur sujet.

La description ci-après de nos propres activités en Belgique dans le cadre d'un groupement parascolaire met en évidence l'importance d'aborder les problèmes de création technique de façon ouverte.

3. UN EXEMPLE DE RECHERCHES EN CRÉATIVITÉ TECHNIQUE PAR LES ADOLESCENTS

En Belgique, l'association NELL se préoccupe, depuis plus de dix ans, d'encourager les enfants à la lecture. Dans ce cadre, je me suis attaché plus particulièrement à l'image des techniques que donne la littérature. Dans un article récent où je déplorais une situation peu favorable aux travaux de l'ingénieur, je concluais que 'changer une telle situation sera long et implique un travail d'apprentissage en profondeur en plus d'une réflexion globale tant sur l'utilisation des techniques que sur l'appréciation que peut en donner l'utilisateur'. Nous avons tenté d'expérimenter dans ce domaine.

C'est ainsi qu'avec des enfants de moins de 12 ans nous avons abordé le problème du recyclage des déchets ménagers, question qui leur est proche: après 'inventaire' du contenu des poubelles, les uns sont partis vers une réutilisation artistique, d'autres vers l'organisation du collectage sélectif. Ces derniers ont été très surpris, ayant 'inventé' entre autres solutions, la récolte par collecteurs souterrains à circulation d'air, de le découvrir en cours de réalisation dans une ville allemande. Les points essentiels de cette activité étaient ceux que cite Tom Hudson, parlant de formation en design industriel:

'The pupils should therefore invent their technology, given only simple demonstration and instruction, sufficient to use the tools efficiently and precisely... This aptitude should be the basis of a continuous structural enlightenment and development, both practical and theoretical, to elucidate the whole appearance and principles of the child's environment, not merely to train him in the production of artifacts.'

Nous avons cherché ensuite à encourager leur esprit inventif et prospectif par la création d'un roman d'anticipation. Pour que l'imagination ne soit pas entravée par le problème de l'écriture, l'équipe de jeunes de 12 à 15 ans collaborait avec un couple d'écrivains qui effectuait la 'mise en forme'. La technique de travail était fort proche de celle que pratiquent actuellement les 'groupes de créativité': évacuation dans l'imagination, confrontation du fil conducteur sorti du rêve avec le cadre réel où l'histoire se place, visite des lieux et prise de documents par les jeunes (en l'occu-
rence, il s'agissait d'un ruisseau qui, au départ de l'étang d'un parc, aboutit en zone industrielle où il se transforme en égout, puis en canal). Ensuite, retour à l'imaginaire, confrontation avec le texte écrit par les professionnels du livre, antagonismes entre 'inventeurs' (les adolescents) et 'réalisateurs' (les écrivains). Cette expérience, décrite en détail par l'un des écrivains (voir réf., J. Held), quoique très enrichissante, a montré les limites d'une action trop étirée dans le temps (deux ans) et l'espace (Bruxelles, Orléans).

Concentrant l'action, nous avons encouragé un groupe scout à préparer certaines réalisations techniques: quelques rencontres ont servi à leur fournir les bases permettant la préparation du matériel, l'essentiel du travail de montage étant effectué pendant le camp.
Leur choix, influencé par l'ambiance 'écologique' actuelle, a porté sur un panneau solaire pour chauffer l'eau, et une éolienne entraînant une dynamo. Si la réalisation et la recherche de solutions techniques propres les a conduits à 'inventer' avec plus ou moins de succès, on pouvait regretter l'absence au départ d'un examen critique du problème à résoudre (eau chaude et éclairage du camp).

Aussi, l'année suivante, avons-nous proposé les activités de manière radicalement différente. Un 'appel de solutions' à un problème réel - pomper l'eau d'un ruisseau pour abreuver un troupeau - a été lancé tout azimut (écoles, radio, etc.). Pour participer au camp, les jeunes devaient envoyer leur solution. La variété fut extrême, depuis l'usage fantaisiste et poétique d'oiseaux porteurs jusqu'au très technique câble électrique à tirer à travers bois sur 500 m. Douze jeunes de 12 à 15 ans, venant de groupes différents, furent invités à un week end de 'fusion des projets'. Ce groupe, très hétérogyène au départ, les jeunes ne se connaissant pas tous, a dû choisir ce qui deviendrait sa réalisation, utilisant pour cela les techniques de groupe et de créativité les plus diverses. Le résultat fut la construction effective deux mois plus tard, au cours de 8 jours de camp, d'un barrage et d'une roue hydraulique raccordée à une micropompe à piston. Ce travail fut entièrement réalisé par l'équipe dirigée par quelques jeunes de 17-18 ans non spécialisés, les conseillers techniques adultes se tenant le plus en dehors possible de la construction.

Nous avons eu là, croyons-nous, une expérience très globale de création qui aura peut-être permis à ses participants de réaliser que la solution des problèmes techniques n'est pas seulement réservée à une élite géniale mais peut-être le fait de tous ceux qui, l'esprit ouvert, s'y attaquent après un certain apprentissage.
4. CONCLUSIONS

Les réactions que nous avons pu enregistrer a posteriori encouragent vivement à poursuivre et développer ce type d'action. Malheureusement, entreprise bénévolement en parallèle à une activité professionnelle chargée, il nous est impossible de faire plus qu'expérimenter occasionnellement. Notre espoir est que l'exemple soit suivi.

Nous pensons avoir mis en évidence le désir de participer à la création technique de certains adolescents. Pour cela, il est essentiel de leur fournir un objectif, un problème à résoudre; au moment où ils sont noyés d'information, il est difficile de les tenter par un supplément de connaissances techniques à assimiler. Par contre, leur désir de comprendre, de critiquer est bien présent s'il leur est offert d'inventer et de construire. A nous d'agir pour que cela soit l'occasion de faire percevoir par les adolescents ce qui est le vrai métier de l'ingénieur.

5. REMERCIEMENTS

Il m'est impossible de citer ici tous ceux qui ont participé aux activités brièvement résumées ci-dessus. Qu'ils veuillent bien considérer qu'ils font partie de ce 'nous' que j'ai volontairement utilisé au cours de la description. Avec l'espoir que chacun d'entre nous poursuivra l'action.

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ABSTRACT

It is frequently stated that creativity, innovativeness and entrepreneurship are, like leadership, inherent in personality and are not able to be taught. It is, however, just as often stated that research 'develops' creativity or that creative researchers can be trained. Again, it is generally agreed that innovativeness can be discouraged by certain restrictive teaching techniques.

Why then cannot engineering students be taught or trained to be more innovative? After all, courses in Marketing, Business, Management, and Art & Design set great store by teaching creativity and have developed teaching strategies and techniques based on the psychology of learning. Further, it seems likely that, having identified potential or active entrepreneurs, their chances of success should be improved by some form of training, say, in financial, production, and personnel management.

During a survey of engineering schools in Europe and the USA, it became apparent to the author that many engineering faculty believe that creativity and innovation can be taught in exactly the same way that 'design' can be taught. Indeed the area of design in engineering presents an ideal medium for the development of creative engineers.

The results of the survey lead to proposals for curriculum development and teaching methods which, it is argued, will encourage, if not produce, more innovative engineers. Suggestions are also made for courses to encourage engineers to become entrepreneurs and to improve their chances of success.

RESUME

On affirme souvent que la créativité, la volonté d'innovation et l'esprit d'entreprise sont, tout comme l'aptitude à occuper des postes de responsabilité, des dons inhérents à la personnalité qui ne peuvent, par conséquent, pas être enseignés. Cependant, on affirme tout aussi souvent que la recherche développe l'esprit de création ou bien qu'il est possible de former des chercheurs créateurs. Et on est aussi généralement d'accord sur le fait que certaines méthodes d'enseignement restrictives peuvent décourager l'esprit d'innovation.

Pourquoi, dans ce cas, ne pas proposer aux étudiants ingénieurs une éducation ou formation visant à les rendre plus innovateurs? Après tout, quand on enseigne le marketing, le commerce, la
gestion ou les arts décoratifs, on attache beaucoup d'importance
au développement de la créativité et pour ces cours, on a mis au
point des méthodes et techniques pédagogiques basées sur la psy-
chologie de l'enseignement. De plus, il semble très probable qu'
après avoir découvert des entrepreneurs potentiels ou déjà actifs,
on puisse augmenter leurs chances de succès en les initiant par
exemple à la gestion financière, la gestion de la production et du
personnel.

Au cours d'une enquête sur les écoles d'ingénieurs en Europe et
aux USA, nous avons découvert que dans un grand nombre de ces
écoles le corps enseignant croit qu'il est possible d'enseigner
tout aussi bien l'art de créer et d'innover que le dessin.
D'ailleurs le domaine du dessin dans le programme d'études des
ingénieurs offre un intermédiaire idéal pour le développement
d'ingénieurs créateurs.

Les résultats de cette enquête permettent de proposer le
développement des programmes d'études et des méthodes d'enseignement,
qui, pense-t-on, pourront encourager, sinon produire, des ingénieurs
plus innovateurs. Des suggestions sont aussi faites en vue d'établir
des cours destinés à encourager les ingénieurs à devenir entrepre-
neurs et à augmenter leurs chances de succès.

ZUSAMMENFASSUNG

Es wird oft behauptet, dass Kreativität, Innovation und Unter-
nehmertum - wie z.B. Führungseigenschaften - angeboren sind und
nicht gelehrt werden können. Es wird jedoch ebenso behauptet, dass
Forschung Kreativität 'entwickelt' oder dass schöpferische Forscher
ausgebildet werden können. Auf der anderen Seite ist man sich dar-
über einig, dass bestimmte einschränkende Lehrmethoden auf die
Initiative, Innovationen herbeizuführen, abschreckend wirken können.

Warum sollten deswegen Ingenieur-Studenten nicht so ausgebildet
werden, dass sie Neuerungen gegenüber aufgeschlossener werden.
Lehrgänge in den Fächern Marketing, Betriebslehre, Betriebsführung
sowie Kunst und Dessin legen auf das Lehren von Kreativität grossen
Wert und es wurden Lehrstrategien und -methoden entwickelt, die auf
der Psychologie des Lernens basieren. Ausserdem scheint es wahr-
scheinlich, dass, nachdem potentielle oder aktive Unternehmer iden-
tifiziert worden sind, deren Erfolgschancen durch bestimmte Aus-
bildungs-Lehrgänge wie z.B. Finanz-, Produktions- und Personal-
management, verbessert werden sollten.

Im Rahmen einer Umfrage in technischen Hochschulen in Europa
und den USA wurde es dem Autor klar, dass viele technische Fakul-
täten der Meinung sind, Innovation und Kreativität können genau so
gelernt werden wie z.B. 'Dessin'. Das Gebiet des Faches 'Dessin'
innerhalb der technischen Kurse ist jedoch ein idealer Träger für
die Entwicklung kreativer Ingenieure.

Das Resultat dieser Umfrage führte zu Vorschlagen zur Entwick-
lung von Lehrplänen und -methoden, die, wenn sie auch keine
In the foreword to the report prepared for SEFI (Tomkins 1979) Professor Carassa states:
'It is in the nature of man to be an innovator' but then goes on to point out that 'Man as an innovator can be inefficient. This inefficiency can stem from his education'.

The present writer would go further and say that education helps people to fit into existing society and jobs (especially in large organisations). It can at the same time totally stifle their natural creativity. But need this be the case? Is it because of what educators teach and how they teach it? Could the system be modified so that creativity rather than uniformity is developed? Even the most conservative of us would accept that creativity should be encouraged in all students even though perhaps only a small number will have the scope or ability to be really innovative in their careers. An examination of various definitions suggests that 'design' is a vital component of the process of creation - invention - innovation. Indeed in most engineering programmes the design courses are the only ones that expect or encourage creativity.

The present paper surveys engineering education in several countries and uses the experience to develop a curriculum structure which, it is believed, would not only raise the innovative level of engineering students but could also be adapted to give a more specialized programme for those with the desire to employ others rather than to be employed.

1. REVIEW OF CREATIVE/ENTREPRENEURIAL ASPECTS OF ENGINEERING PROGRAMMES IN SEVERAL COUNTRIES.

Engineering education - especially the more it approaches engineering science rather than technology - does not place a lot of emphasis on creativity and innovation. Is this because we try to pack in as much of the explosion of knowledge as possible leaving no room for what might be considered fringe topics? Or is it because engineers and scientists think analytically and critically while innovation and entrepreneurship require synthesis and the switching off of negative, critical attitudes?

No Department of Engineering admits that its students aren't creative and innovative. It is my belief that, if this is true, it is because of the personal qualities of the students and that they are likely to be less creative at the end of most Third Level courses than at the beginning.

As Tomkins (1979) points out, there are three areas of ability required by an innovative engineer:
- Knowledge - details of relevant science and its applications (termed the cognitive domain (Bloom 1956).
- Skills - creativity, problem solving, decision making, etc. This could also include manual skills.
- Attitudes - positive thinking, motivation, confidence and desire to break new ground, desire to succeed, flexibility, etc.

(Affective domain).

In most engineering courses covered in the countries of this survey, the major emphasis is placed on knowledge, with skills a poor second. Attitudes are difficult to 'teach' and in most courses are not given formal attention. Unfortunately these attitudes are the most important factors in developing innovation and entrepreneurship. The aspects of creativity and innovativeness are best developed by active learning methods and, in engineering programmes, design courses and projects are useful vehicles. These are often made real by using existing industrial problems, usually in the area of engineering specialisation, and sometimes direct contact with an industrialist.

The latter aspect can be taken to its logical conclusion by actually giving the student a problem while in an industrial environment. This work experience is encouraged at many colleges but is formalised in Cooperative Education Programmes (co-op) or Sandwich courses where students spend one or more periods doing a monitored project in industry.

Universities have approached the problem of technological innovation in a number of ways.
- By increasing the emphasis on creativity in engineering courses, mainly through design projects.
- By designing course units in the area of entrepreneurship for undergraduate engineers to elect in their course credit system.
- By designing specific courses usually at Masters Degree Level in Entrepreneurship and Small Business Management.
- By encouraging faculty to innovate and become entrepreneurs.
- By employing on a full-time or part-time basis faculty who themselves are successful entrepreneurs.
- By setting up 'Innovation Centres' associated with Universities.

The variety of approaches have all produced useful results - they show that an encouraging environment can stimulate people to become entrepreneurs. Some of the approaches are now briefly summarised:

(a) TEACHING CREATIVITY

Applications of concepts and theories of educational psychology to the development of creativity are well known. Writers like de Bono, Jones, Osborn, Zwicky and others have detailed the techniques, both systematic and intuitive.

Engineering students have a particular difficulty in this step of the problem-solving process. Their training is generally in an intensive analytical framework, using supplied necessary and sufficient information, precise (although often unrealistic) data and well proven laws to produce specific answers (usually numerical, 'to several places of decimals'). When they are asked to tackle an
open-ended problem with limited relevant information and, perhaps, a wealth of irrelevant facts, they often feel quite at sea and complain that the problem is not a part of their course. Staff, especially we older ones, often feel exactly the same thing.

In courses in Business Studies and Management such techniques are widely accepted and phrases such as: List Making, Decision Trees, Morphological Analysis, Mutual Association, Analogy, Brainstorming, Synectics, Lateral Thinking appear in many syllabi.

In the areas of Industrial and Production Engineering, which may strongly overlap certain aspects of Management courses, these processes are often used but they would generally be reviled by academics in Departments such as Mechanical, Electrical, Chemical Engineering especially the further the methods move from systematic towards the intuitive.

In several Engineering Schools, however, experiments are being tried to encourage creativity. It is interesting to note that, while some lectures may be given on techniques for idea generation (creativity) the major pedagogy is through active learning in design and problem solving situations. 'Design is doing' and one gets better at design by designing not by attending lectures on The Theory of Design.

Similar statements apply to other attributes in the affective domain e.g. at M.I.T. they believe that 'Innovation' can be taught or at least encouraged by a concentration on open-ended problems rather than by lectures on creativity.

Perhaps it is also the dictum that 'practice makes perfect' that convinces academics that research develops creativity, in that it is practice in open-ended problem solving. If this same solution is applied to younger undergraduates it should be even more successful, as they have had less indoctrination in the rigid, analytical approach of most courses. A direct, perhaps obvious, example of the application of this philosophy is in the involvement of senior students in research projects with post-graduates.

The development of creativity is usually left to the design parts of course, so it would be useful to examine some of the trends in this area. Some typical situations include:

(i) Introduction to Design courses often require students to do a series of team mini-projects the aim of which is to design and build a device which will out-achieve devices from the other teams. The devices will be different at different stages of the course but will generally have specifications of materials to be used, or maximum weight, cost, etc.

One example would be to design a 'mouse' driven only by a mousetrap spring that will move the furthest distance down the laboratory floor. Students might even be given the choice of an alternative energy source such as that of a specified weight falling through a specified height. The projects can be more difficult e.g. turn at 90° after two metres or climb over obstacles. Such projects not appeal to the vital COMPETITIVENESS required of entrepreneurs but can be designed
to combine ingenuity and manipulative skills with the scientific principles taught in other courses. They also bring back into Engineering courses the element of FUN which academics seem to consider anathema but which strongly increases motivation in the student groups.

(ii) In later years these design projects became more SERIOUS in that more 'useful' devices can be designed, built and tested. An annual competition which has assumed National status in the USA is a one-man vehicle capable of travelling the greatest distance around a specially difficult track on one gallon of petrol. When it is noted that the present record for the vehicle is in the region of 700 miles one can understand the amount of back up mathematical analysis in aerodynamics, stress analysis, strength/weight ratios, power/weight ratios, thermodynamic efficiency, friction, etc. that goes into the design.

(iii) Several Engineering Schools run interdisciplinary (Demetry 1978) or Urban oriented (Smith 1979) Design Projects in which a group of students try to solve a real problem of society, usually the local community. These may or may not be engineering-based but problem-solving methodology can produce useful solutions.

(iv) Projects in the Final year will be more advanced again and tend to be more specialised in the student's major study area. Examples chosen at random include:
- Laser diode photoelectric sensor;
- Low cost load cell;
- Rotary blade style fertiliser mixer;
- Part sorting and loading system;
- Non-destructive test method for annealed connector pins.

Many of these projects are industry sponsored.

In Scotland and Ireland an interesting innovation is the development of courses in Industrial Design Engineering. These attempt to blend engineering principles with more aesthetic design and are oriented towards commercial products. Students from these courses certainly use their creativity to a high degree. One graduate from the course at my institution is now working with the Innovation Centre at NIHE, taking a mechanical product for agricultural purposes, developed in an undergraduate project, through to the market place.

The German approach to design education is more methodical and tends to concentrate on traditional machine design. The systematic approach to design (Beitz and Pahl 1981) does not require engineers to be very innovative and, perhaps, might often be termed 're-design'.

The Dutch have combined the American and German systems and both 'mousetrap machines' and 'non-return valve' type projects exist. At the Technische Hogeschool at Delft a Department of
Industrial Design Engineering, developed initially from a School of Architecture, has been in operation for about fifteen years. The course (Eekels 1981) is essentially aimed at product design and development and is truly interdisciplinary, with 'hard' engineering intimately mixed with management, marketing and aesthetic design. Much emphasis in the Delft course is placed on creativity partly by class work but mainly through projects and problem solving. Methodology of design is taught but they believe that 'problem solving is best done by solving problems' and this is repeated throughout the five-year course.

In France engineering education is traditionally mathematical and analytical but a few of the newer schools are making conscious efforts to change (modernise?). For instance the new Universite de Technologie de Compiègne has developed, from a mechanical engineering department, a five year Dip. Ing. in which the final three years specialise in industrial design. It is worth noting that student exchange programmes are mounted with Delft and with Cranfield in the U.K.

Another radical French initiative is represented by the Ecole Superieure d'Ingenieurs en Electrotechnique et Electronique in Paris. The institute offers (Monzat 1979) a five year modular Dip. Ing. course in electronics engineering in which the emphasis is on learning through small group projects with a minimal amount of lecturing. The final year is devoted entirely to small group projects on industrial problems funded by the company concerned.

This brief report cannot be a comprehensive survey, especially as changes are taking place constantly throughout the education systems of all the countries. It is apparent that most educators realise the importance of broadening the course content and attitudes of students and that there are many equally valid ways to do this. It does seem, however, that the trend is toward student 'learning' rather than faculty 'teaching' and that group projects are more-and-more replacing the older chalk-and-talk method. This has been noticed in the universities visited in France, Ireland, Netherlands, UK and USA and also in reports from other countries not visited, e.g. Belgium (De Meester et al 1978 and Buyse et al 1978) and Denmark (Nielsen 1979).

(b) ENTREPRENEURIAL COURSES

The teaching of entrepreneurship in undergraduate engineering programmes is almost non-existent, although in some an elective/option may be available from a range of topics which could include aspects of industrial management and entrepreneurship. Students following courses in Industrial or Production Engineering are more likely to be involved than the more 'science-based' courses such as Mechanical or Electrical Engineering.

Vesper (1980) has prepared a compendium of courses operating in North America and shows that between 1970 and 1980 the number of schools with courses in entrepreneurship increased from about...
30 to 160. Most of these courses are given by Business Departments but the latter figure includes 22 Departments of Engineering. However, the telling statement is made:

'Engineering curricula seem inevitably to be burdened with such a high proportion of basic engineering analysis courses, all of which are justified as necessary to a basic engineering education, and consequently, although entrepreneurship may be needed ultimately to translate the creative output into the market place, it can be difficult for that subject matter to be squeezed into the crowding of basic engineering technology offerings.'

This is recognised as a serious problem by all engineering educators - and, no doubt, by science and management educators also. The entrepreneurial courses cover the range from one individual course unit to a complete undergraduate or post-graduate specialisation and involve units such as Enterprise Development, Entrepreneurial Strategy, New Venture Management, etc. In some of the universities, NSF Innovation Centres co-operate with teaching departments by supplying courses and giving students the opportunity to develop inventions through to commercialisation.

At postgraduate level Master of Industrial Engineering (M.I.E.) courses are often closely associated with Master of Business Administration (M.B.A.) courses. This results in the MIE courses containing topics such as New Product Development, Small Scale Manufacturing, Entrepreneurship, and teaching methods include the use of case studies and industrial clinics.

2. ENGINEERING CURRICULA FOR INNOVATION

What, then, can we learn from the preceding survey and discussion and how can we use this information to design an 'optimal' engineering curriculum which engenders in graduates an innovative attitude - both in the direction of creativity and of entrepreneurship?

It seems to the present writer that the major modification required to existing teaching programmes is in the approach rather than in the content. It was argued (Petty 1978) at a previous SEFI Congress that the detailed content of syllabi is almost immaterial to the development of a successful engineer.

The traditional lecture approach is probably out-dated in general - it is certainly not conducive to creative or innovative attitudes. Lecturers should more often hand out notes, reference material, problems, etc, and use class contact time for two-way discussion. This could be based on case studies of successful and unsuccessful innovations and innovators. Some of these meetings could involve industrial innovators or designers - or even artists. Laboratory work should figure strongly - but not the traditional, boring laboratory exercises that have run, often unchanged, for several years. Many could easily be made 'open-ended' and left to
the students to create their own techniques and solutions. It is realised that, in Ireland for instance, most first year students have often had little experience in a laboratory or workshop and some 'hands-on' work may be necessary. However, many standard laboratory experiments to demonstrate well-known phenomena could be more efficiently handled by demonstration, tape-slide sets, video tapes, film loops, etc.

It has been stated that entrepreneurs are mavericks; they are difficult to specify, simply because they are individualistic. They are very goal-oriented and tend to find traditional (rigid) academic programmes irrelevant to their needs and interests. This would suggest that a flexible programme with a wide range of electives, including non-engineering topics, together with individual and interdisciplinary team projects would be a more suitable education for them, as they would be happier in an atmosphere where they make their own decisions on educational packages rather than be forced to be concerned with a full coverage of current knowledge in a specialist field.

It must also be conceded that many engineers will not take the entrepreneurial route for several years after graduation and that detailed educational back-up will be a major assistance only in a short, intensive, continuing education mode. Nevertheless windows could be opened and attitudes formed by initial education.

Formal teaching should also be interspersed with time spent in the 'real world' or on 'real world problems'. This could vary from industrial or urban-based projects, to sandwich courses or to post-experience Continuing Education. Discussion sessions with successful entrepreneurs and industrial leaders parallel the traditional master/apprentice relationship, which Timoney (1979) suggests is the ideal method of training design engineers.

It seems that a start has been made on the teaching of commercial innovation and entrepreneurship in Business Departments through courses in areas such as Economics, Accounting, Financial and Personnel Management, Marketing Product Development, Enterprise Development, Entrepreneurial Strategy, New Venture Management. The primary need is thus for closer collaboration between Business Faculty and their lagging Engineering colleagues.

The question then becomes how do we introduce all these into a course of limited duration and often by staff who are already at full stretch? The answer must be 'with difficulty' but, what will certainly be required is a flexible approach; local situations vary tremendously and there will be a variety of constraints on any proposed changes ranging through personal, administrative, structural, social and political.

The proposal of one specific course in engineering to improve creative and entrepreneurial attitudes is hardly possible in view of different regional and national characteristics, attitudes, environment etc. I shall propose, as an example therefore, a 4 year first degree course with a student intake having a broad range of
subjects generally at a lower level than English 'A levels'. Such an intake would be typical of university entrants in North America, Ireland, Scotland and many European Countries. (The Mathematics and Science in Year 1 of this course would be broadly equivalent to A level).

Figure 1 illustrates the proposed curriculum and is based on the following premises:
- Engineering may be defined as the practical application of science for the benefit of mankind.
- An Engineer is essentially a problem solver and needs to nurture his creative ability.
- Design is the process of solving problems. It is a process of synthesis that must be practiced rather than talked about. It is strongly believed that Design Projects are vital to the development and growth of the innovative abilities of students.

NOTES ON FIGURE 1

1. Student work loads are not specified in overall terms but it would normally be expected that approximately half of the weekly load would be face-to-face with faculty in lecture/tutorial/seminar situations. The remaining time would require only general and occasional guidance by faculty while students worked on designs and set problems, and interacted with computers, workshop equipment, drawing offices, etc.

2. It may be desirable to have some more traditional laboratory exercises in year 1 (and 2?) in order to give students a hands-on feel for certain equipment and to give them the rules for laboratory behaviour. However, the argument that comprehensive laboratory experiments relating with lectures is necessary is considered fallacious. In most cases they do not correlate either in time or content and are seldom comprehensive of class coverage. On the other hand projects create a 'need to know' attitude which strongly motivates students so that they achieve a greater understanding while at the same time developing their self-learning ability necessary for Continuing Education.

3. Short projects could range from the 'one afternoon' to the 'three week' type. The former may help to concentrate the mind while the latter helps students to understand planning and methodology.

4. Some projects could be performed individually but team projects are educationally better. They may be a little more difficult to assess - but perhaps education is more important than assessment.

5. Projects throughout the four years should generally be of the DESIGN-BUILD-TEST variety with an ever increasing level of technology (and commercial orientation where appropriate). Some of this Project time should, ideally, be spent in industry, e.g. on a co-op/sandwich course.
Fig. 1. Proposed curriculum for a 4 year degree course in engineering.

6. An attempt should be made to co-ordinate schedules to allow an interdisciplinary group to work on some of the projects. For instance, in years 3 and/or 4, projects may relate not only to design of a technical product but also to preparation of a full business plan for its commercial manufacture.

7. Free Elective allows students to learn one specialism properly e.g. foreign language or a series of management topics - including entrepreneurship and related topics.

8. The Communications and Design elements are the formal contact part of the Projects. In toto they are intended to equip graduates with the technical and social skills necessary for them to
be creative engineering designers. Such skills would include:
Graphical skills - sketching and formal drawing;
Practical skills - tools and production processes;
Communication skills - verbal, written, graphical, models;
Methodological skills - problem definition; generation of alternative solutions (by logical and intuitive techniques);
decision making;
Team-skills - social and productive integration.

There are many subsidiary points which could help to strengthen the course in the directions of innovation and entrepreneurship such as:
- Set up an interfaculty group of engineering and business/management faculty to progress the development of programmes.
- Some aspects of faculty industrial research and consultancy projects could be delegated to or discussed with senior students.
- Faculty promotion systems should take into account unpublishable industry-sponsored research, high level consultancy, development of innovative programmes and teaching methods - as well as, or instead of, the usual published academic research.
- Man is a competitive animal - this talent should be encouraged by holding design competitions. If there are not enough national or international competitions, industry should be asked to establish prizes for innovative student projects or research work.

3. SUMMARY & CONCLUSIONS

1. Engineering courses do not, in general, encourage innovation or entrepreneurship. Indeed, having invested a number of years in University level education, graduates are, if anything, less inclined to go it alone than to progress through the normal route to a regularly paid job.

2. The easiest vehicle for remedying the deficiency in creativity is the design project - although other active learning methods provide scope for creativity, initiative, and decision-making. Lectures will not. A creative student evolves after constant, repeated practice at being creative.

3. An interest in entrepreneurial activity could be encouraged by a variety of methods, e.g. core courses, or at least electives, in entrepreneurial study areas; discussions with invited entrepreneurs, innovators and very creative people; involvement in faculty consultancy; etc. Such courses would probably need to be repeated more intensively in the Continuing Education mode.

4. These attitudes are engendered by their injection into the range of engineering courses rather than by an isolated course in innovation - and certainly not by a passive lecture course.

5. Modular Courses, especially those with strong industrial interaction (such as co-op/sandwich arrangements), seem to be the most amenable to adoption of entrepreneurial content but innovative attitudes can be inculcated by modification of the instruction method towards more active student participation in
their educational process.

6. There will be a great resistance at all levels to the changes suggested. Interdepartment liaison and mutual respect between Business and Engineering will have to grow; faculty will have to change their methods of teaching; Assessment Boards will have to give more freedom to individual teachers; and so on.

7. In spite of these and other problems the movement is under way. Visits to a number of Universities in Europe and North America have shown a growing conviction that national prosperity on the one hand and student motivation on the other require these basic changes in curricular freedom and learning methods.

REFERENCES


Die Ausbildung von Ingenieuren dient unmittelbar der ständigen Sicherung des wissenschaftlich-technischen Fortschritts in der industriellen Produktion. Dabei müssen die Absolventen
- über ein solides Wissen verfügen
- die Fähigkeit besitzen, diesen Wissen anzuwenden
- sich für die bewusste Erfüllung der gesellschaftlichen Aufgaben engagieren.

Daraus ergeben sich an die Ausbildung und Erziehung dieser Absolventen einige Anforderungen, die durch das Studium erfüllt werden müssen:

   - optimales Verhältnis von gesellschaftswissenschaftlicher, naturwissenschaftlicher sowie technischer Grundlagenausbildung einerseits und exemplarischer Spezialisierung anderseits.
   - Einheit von Ausbildung und ständiger Weiterbildung

2. Die disziplinorientierte Ausbildung an der Hochschule muss zugleich deren problemorientierte Anwendung trainieren, denn alle Arbeitsaufgaben des Ingenieurs sind interdisziplinär und problemorientiert.
   Dazu werden als Möglichkeiten angeboten
   - selbständige wissenschaftliche Arbeiten im Studienprozess,
   - Industriepraktika,
   - Teilnahme an Wettbewerben und Ausstellungen,
   - Studentische Konstruktions- und Entwurfs labor.


Zur Sicherung der Komplexität der Ausbildung ist die organische Verbindung der verschiedenen Lehrveranstaltungen sehr bedeutsam, um vor allem neue wissenschaftliche Erkenntnisse an den Grenzen traditioneller Wissensgebiete schnell zuorden zu können.
ABSTRACT

Paradoxically, innovation in the training of engineers is going through a phase of self-criticism. In this connection, the Swiss Federal Institute of Technology in Lausanne (Switzerland) has introduced in 1980 a new training programme called: "Mankind - Technique - Environment", and inserted it in the programme of studies of its nine departments. The aim of this training course is to develop among the students certain faculties which will enable them in the future to use their scientific and technical knowledge in the best possible way, to be both wider and more creative, so that initiative governs the whole of their professional activities and makes of them leading innovators in the technological, as well as in the human and social, fields.

RESUME

L'innovation dans la formation des ingénieurs passe de manière paradoxale aujourd'hui par son autocritique. L'Ecole Polytechnique Fédérale de Lausanne (Suisse) a introduit à ce sujet depuis 1980 un nouveau programme de formation intitulé: "Homme - technique - Environnement", intégré au plan d'étude de ses neuf départements. Ce programme de formation a pour but de développer chez les étudiants certaines compétences qui leur permettront d'utiliser ultérieurement leurs connaissances scientifiques et techniques d'une manière plus large et plus créative, de façon à ce que l'esprit d'entreprise préside à l'ensemble de leurs activités professionnelles et en fasse des vecteurs d'innovations à la fois technologiques, humaines et sociales.

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eine Kompetenz zu entwickeln, die es ihnen später erlaubt, ihr wissenschaftliches und technisches Wissen besser und kreativer auszunutzen, sodass ihre berufliche Aktivität von einem initiativen Geist getragen wird, und sie dadurch zu führenden Innovateuren auf technologischen, menschlichen als auch sozialen Gebieten zu machen.

INTRODUCTION

Les notions d'innovation et de méthodes innovatrices concernant l'enseignement tertiaire et polytechnique en particulier ont toujours été rattachées, en termes d'efficacité, à l'adéquation d'une certaine offre et d'une certaine demande.

Suivant l'évolution fluctuante de l'histoire économique et sociale, et des besoins à satisfaire, les critères d'efficacité ont été à ce sujet de nature tour à tour sociologique, économique, politique, démographique, pédagogique, etc.

Jamais le sens de cette adaptation n'avait pris la tournure philosophique et éthique à laquelle la contraint aujourd'hui l'aspect mésologique des problèmes et la mise en question téléonomique de notre civilisation.

Rendues responsables d'avoir favorisé une progression asymptotique des technologies, aveugle aux implications écologiques et humaines qu'elle allait entraîner, les Ecoles d'ingénieurs ont été amenées un peu partout à chercher comment sensibiliser et comment former leurs étudiants à une nouvelle forme de déontologie "axiologique", ... qui ne nuise cependant ni aux exigences mouvantes du marché du travail, ni à la conformisation des structures sociales en place !

HISTORIQUE ET CONTEXTE

A l'instar des premières expériences entreprises à ce sujet par l'Institut de technologie du Massachusetts, l'Université Duke (Caroline du nord), l'institut de technologie de l'Illinois ou par l'Ecole des Mines de Nancy par exemple, l'Ecole Polytechnique Fédérale de Lausanne (EPFL) a tenté depuis 1958 déjà, d'introduire des cours de sciences humaines dans son programme d'études. Or, comme ailleurs (USA, Japon, Europe de l'est, etc.), les résultats ont été décevants.

L'historique des travaux successivement accomplis depuis cette époque par les divers groupes de travail, les commissions ou les experts tour à tour chargés par l'EPFL de résoudre cette question
révèle toutefois une prise de conscience progressive de la pluri- et interdimensionnalité nécessaire de la solution.

L'EPFL est en effet passée de projets centrés sur une idée ("compléter la formation technique des étudiants par une culture générale relevant des sciences humaines"), à d'autres, centrés sur les apprenants ("leur fournir les moyens de mieux comprendre l'interface de la technologie et de la société"), avant d'adopter en 1980 une démarche qui s'inscrit dans une perspective davantage systémique, où l'attention a moins été portée sur l'opportunité de tel ou tel contenu ou sur les obligations des étudiants par exemple, que sur le rôle et l'influence respectifs des partenaires à l'intérieur de structures d'encadrement à la fois souples et intégrées.

Etant donné cette optique, il est important de souligner que l'EPFL est actuellement avec celle de Zurich la seule université technique en Suisse, et l'une des plus petites, puisqu'elle compte à l'intérieur de ses 9 départements (génie civil, génie rural et géomètre, mécanique, électricité, physique, chimie, mathématiques, matériaux, architecture) environ 2000 étudiants, 100 professeurs et 700 employés répartis entre la recherche, l'enseignement et l'administration.

Si ces caractéristiques contextuelles n'ont guère remis en cause certains principes de pertinence, d'intégration, ou d'imprégnation mis en évidence en 1974 déjà par l'UNESCO (1), elles en ont par contre déterminé les applications administratives et pratiques.

DESCRIPTION DU NOUVEAU PROJET D'ENSEIGNEMENT NON TECHNIQUE

Ce nouveau programme d'enseignement non technique poursuit trois objectifs correspondant à trois unités pédagogiques distinctes :

1. La première unité, intitulée "instrument de travail", vise à développer, en particulier chez les étudiants de première année, certaines compétences personnelles, pratiques et méthodologiques susceptibles de faciliter leurs études en général : langues étrangères (allemand, anglais, français), expression orale, techniques de mémorisation, lecture rapide, prise de notes, rédaction de rapports de synthèse, etc. Les cours sont facultatifs et n'interviennent pas dans les conditions de promotion.

2. La seconde unité offre aux futurs ingénieurs de 3ème et 4ème année l'occasion

- de situer leur travail à l'intérieur de l'environnement social, psychologique, économique, politique et écologique où ils seront appelés à évoluer,
- de prendre conscience de leur responsabilité personnelle et professionnelle et
- de découvrir les moyens nécessaires pour les assumer.

La gestion de cette unité dépend des départements, étant donné la spécificité avec laquelle se présentent pour eux ces questions. Tous les étudiants sont tenus d'effectuer un travail personnel, dans lequel ils considèrent les incidences réciproques qui s'exercent entre tel ou tel problème ou projet technique et le contexte humain où il s'inscrit. Chaque département établit une liste indicative de sujets. Ceux-ci font l'objet par la suite d'une négociation entre les étudiants et les enseignants, ou les consultants des branches techniques et non techniques concernés. Afin que les étudiants trouvent à l'Ecole les connaissances nécessaires pour traiter le type d'interface qu'ils analysent, chaque département leur propose un certain nombre de cours d'intérêt général ou particulier. Ceux-ci vont ainsi des "aspects socio-culturels de l'évolution technologique" à "la méthode Pert", en passant par exemple par un enseignement jungien: "les deux langages: langage du psychisme et langage de la pensée", un cours d'économie de la consommation, ou de philosophie: "Logique et épistémologie", etc.

Le rapport de ce travail doit être rendu par l'étudiant au plus tard à la fin de la 4ème année. La note qui lui est attribuée est incorporée à celles des branches pratiques et intervient dans les conditions d'accès aux épreuves théoriques de diplôme.

3. La troisième unité cherche à rendre les futurs ingénieurs opérationnels sur d'autres plans que celui de leur spécialisation technique, afin qu'ils puissent assumer les diverses fonctions d'encadrement, de direction, de gestion, de marketing ou de sélection qu'exige de plus en plus souvent l'exercice quotidien de leur métier.

Cette unité comprend ainsi des cours de droit, de gestion comptable en financier, de planification d'entreprise, de psychologie, de sociologie, d'hygiène industrielle, d'introduction aux pays en voie de développement, de législation urbaine, etc.

Ces cours, bien qu'organisés par les départements, sont accessibles à tous les étudiants. Certains sont obligatoires et d'autres à option. Ils font l'objet, suivant les règlements d'application du contrôle des études propres à chaque département, du même type d'évaluation que les branches techniques.
OBSERVATIONS ET PRONOSTIC

Si la première et la troisième unité de ce programme concernent essentiellement l'insertion, l'adaptation et l'efficacité du futur ingénieur dans le contexte professionnel où il exercera sa spécialité selon des critères de rendement industriel et économique habituels, la deuxième unité en est par contre une certaine remise en question.

C'est essentiellement dans cette forme de contradiction (nécessaire) que réside l'originalité de ce nouveau projet, bien que sur le plan psychologique, elle soit vécue par certains étudiants et par certains professeurs comme un insupportable "double-bind" : comment être un ingénieur simultanément sceptique et convaincu ? Cette situation d'angoisse explique sans doute chez ces derniers deux formes de comportement symétriques :
- soit "d'agressivité ou d'indifférence" manifesté par exemple par la faible fréquentation de certains cours non techniques obligatoires, par certains articles pamphlétaires dans le journal interne de l'Ecole ou par une certaine lenteur dans l'application généralisée de ce programme d'enseignement non technique,
- soit de "culpabilité" exprimée par la désertion de cours techniques, par un certain désinvestissement affectif de l'image professionnelle de soi, par l'adhésion individuelle à diverses formes sectaires d'irrationalisme, ou par des mouvements d'opposition contre l'extension de la section des sciences militaires à l'EPF de Zurich par exemple.

Mais la majorité de la communauté, notamment estudiantine, semble quant à elle trouver cette démarche plutôt positive, même si l'esprit dans lequel elle l'envisage est encore relativement scolaire, et si certaines questions liées aux contrôles des études la divisent.

Bien qu'on ne puisse pour l'instant pas se prononcer sur l'impact réel qu'aura cette nouvelle forme de sensibilisation et de formation non technique sur les étudiants, certaines observations permettent de penser que la forme du projet actuellement en cours correspond enfin, à quelques améliorations près, à ce que l'EPFL recherchait depuis 20 ans.

L'intérêt particulier que les étudiants semblent manifester par exemple pour la psychologie, tant dans les cours qui leur sont proposés que dans les thèmes HTE qu'ils choisissent, est en ce sens un indice réjouissant, puisqu'il dénote de leur part la volonté de pénétrer dans un domaine d'étude et de réflexion qui, mieux qu'un autre, les implique en même temps directement comme sujets.
Conclusions

Les moyens mis en œuvre par l'EPFL contribueront-ils réellement à supprimer la juxtaposition des deux cultures fermées l'une à l'autre et dont C.P. Snow pensait avec raison qu'elle caractérise notre civilisation ? Sans doute, à condition toutefois que
- les enseignants des branches scientifiques et techniques prennent conscience qu'ils sont ici les premiers vrais vecteurs de changement, et que leur influence décisive sur les étudiants se situe à deux niveaux :
  - leur propre attitude personnelle à l'égard des sciences humaines,
  - les méthodes pédagogiques qu'ils utilisent dans leurs cours, étant entendu qu'un cours ex cathedra par exemple ne développe pas autant l'autonomie, la créativité et le sens des responsabilités que des formules didactiques plus individualisées, ou que des enseignements par étude de cas, par projet ou par découverte guidée.
- les chargés de cours en sciences humaines employés régulièrement par l'EPFL bénéficient progressivement d'une formation universitaire où les disciplines qui sont les leurs ne leur soient plus enseignées selon l'idée qu'elles se font d'elles-mêmes en tant qu'entités épistémologiques distinctes et séparées, mais suivant leur rapport, et dans une perspective qui intègre (en sens inverse) les problèmes et les moyens d'analyse de la technologie.

Mais l'avenir à court terme se jouera ici tout d'abord, à notre avis, sur l'attitude que les organes de décision prendront en face des difficultés éventuelles diverses qui jalonneront cette nouvelle expérience.

Nous souhaitons quant à nous qu'ils ne considèrent pas trop vite celles-ci comme des problèmes à résorber, mais au contraire comme des phénomènes qui auront peut-être pour fonction cachée de permettre à l'Institution de ne pas changer !

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ABSTRACT

The technological change initiated by microelectronics is accompanied by a great innovative process. It is unavoidable to specialize the engineering education in an early stage. So, an integralist is needed, who is able to obtain new kinds of knowledge from the results of a specialized team. The change from specialist to integralist, however, is only possible in an atmosphere of intellectualism, which is based on a well-founded general education.

RESUME

Le changement technologique provoqué par la micro-électronique est accompagné d'une dynamique d'innovation inconnue jusqu'ici. Par conséquence, ce développement oblige à spécialiser la formation des ingénieurs dès le début. C'est pourquoi on a besoin d'un intégraliste, sachant les méthodes et les résultats d'un groupe de spécialistes, pour en obtenir des connaissances d'une vue élévee. Mais le changement d'un spécialiste à un intégraliste n'est possible que dans une atmosphère exigeant une éducation générale bien fondée.

ZUSAMMENFASSUNG


Der Einbruch der Mikroelektronik und ihre Auswirkungen sind dabei, den Menschen und seine Arbeitswelt wie überhaupt unser ganzes Leben durch neue Denkmodelle sowie durch eine geänderte Produktions-
struktur und Arbeitssituation aber auch durch veränderte Qualifikationsverhältnisse des Personals ganz wesentlich zu beeinflussen. Es handelt sich um einen tiefgreifenden technologischen Wandel, um eine technologische Revolution, begleitet von einer bisher kaum gekannten Innovationswelle. Mikroprozessor und Mikrocomputer sind gleichsam Repräsentanten dieses Strukturwandels.

Die Grossintegration macht es heute möglich, auf einem Silizium-Kristall von nur 4 x 5 mm² Fläche ganze Schaltungen unterzubringen, für die man noch vor 15 Jahren etwa 38,000 einzelne diskrete Transistoren und Dioden von insgesamt 8,5 kg benötigte. Die LARGE SCALE INTEGRATION, die LSI-Technik, brachte die Integration ganzer Schaltungen, die VERY LARGE SCALE INTEGRATION, die VLSI-Technik, wird uns die Integration ganzer Systeme auf etwa ein cm² Fläche bringen. Neue technische Anwendungen der Mikroelektronik mit noch unbekannten Möglichkeiten, sowie neue Technologien und Produkte werden uns noch zahlreiche ungeahnte Perspektiven eröffnen. Gleichzeitig setzt uns diese Entwicklung dem Druck einer bisher kaum vorstellbaren Innovationsdynamik aus. Produkte der Elektronik sind teilweise nach zwei bis drei Jahren überholt und veraltet. Man schätzt, dass Nachrichten- und Datentechnik bereits in wenigen Jahren etwa 50% ihres Umsatzes mit vor zwei Jahren noch kaum oder gar nicht bekannten elektronischen Bauteilen betreiben werden. In drei bis fünf Jahren dürften 75% der Bauelemente der Elektronik neue Erzeugnisse sein.

Dieser nicht mehr aufzuhaltende Strukturwandel ist dabei, alle Zweige der Technik zu durchdringen. Oft ist der Einsatz von Mikroprozessor und Mikrocomputer nur deshalb noch nicht möglich, weil zunächst die Sensoren für die benötigten Eingangsdaten entwickelt werden müssen. Geboren aus einem Problem der Raumfahrt, das Lösungen suchte, wurde der Mikroprozessor nun eine Lösung, die Probleme sucht. Hierfür müssen wir bereits heute Ingenieure ausbilden und darauf vorbereiten, sich jeder technischen Entwicklung in ihrem Fachgebiet zu stellen.

Diese Ingenieure müssen fähig sein, die Tendenzen und Trends in ihrem Fachgebiet und im Umfeld ihres Fachgebiets zu erkennen, sich rechtzeitig darauf einzustellen und, falls erforderlich, sich auch entsprechend umzustellen. Schliesslich müssen sie die Grenzen und die eventuellen Gefahren eines technologischen Wandels erkennen und erfassen können, aber auch mit Widersprüchen etwa zwischen Ökonomie und Ökologie fertig werden. Diese Aufgaben verlangen einen erweiterten Bildungshorizont, dessen Notwendigkeit bei der Technikvermittlung nicht mehr übersehen werden darf, falls der Ingenieur auch weiterhin Entscheidungsaufgaben übernehmen soll. Wir brauchen also Ingenieure mit einem erweiterten Bildungshorizont, mit mehr Allgemeinbildung. Nicht nur Naturwissenschaft und Technik oder nur Human-, Wirtschafts- und Sozialwissenschaften werden benötigt, wir brauchen auch noch eine Philosophie, die unserem wachsenden Wissen ein entsprechend waches Gewissen zur Seite stellt und zu bewahren verhilft, die aber auch verhindert,
dass Denken nur noch zu einem programmierbaren Prozess, zu einer computerunterstützten Denkerstörung wird, gewonnen aus einer Kom-bination logischer Verknüpfungen.

Grundlage jeder Allgemeinbildung ist zunächst die Pflege der eigenen Sprache, um sich verständlich, präzise und klar ausdrücken zu können. Mancher Ingenieur musste nur deshalb im Berufsleben versagen, weil er dieses nicht gelernt hatte. Kaum etwas haben wir mehr verlernt, als die Beherrschung und Pflege der eigenen Sprache. Sie wurde zum blossen Informationsträger degradiert. Wer aber nicht mehr zwischen Form und barbarischer Stillosigkeit zu unterscheiden vermöge, kann auch kein schöpferisches Verhältnis zur Kultur haben und auch nicht kreativ wirken. Der Gedanke wird nur noch Ware und jede Ausbildung zu einer Anhäufung sterilen Wissens.


Schliesslich verlangt der Strukturwandel ausser fachlicher Flexibilität auch berufliche Mobilität, d.h. die Bereitschaft, dorthin zu gehen, wo man gebraucht wird. Eine abgeschlossene Berufsausbildung ist heute noch lange nicht gleichbedeutend mit dem Anspruch auf einen passenden Arbeitsplatz; sie bietet nur eine Chance dazu.

Betrachtet man nun noch die derzeitigen Möglichkeiten der Ingenieursausbildung, so bietet sich uns zusammengefasst folgendes Bild: 1. Das Wissen in einem naturwissenschaftlich-technischen Teilgebiet hat sich bereits nach drei Jahren, spätestens nach acht
Jahren verdoppelt. In einer solchen Situation bringt eine Verlängerung des Studiums keine Lösung.


Der Wunsch nach 'Universalingenieuren' kann heute nur noch einen 'Universaldilettanten' gebären. Während dessen ist das Ueberborden des Spezialistentums dabei, den Superspezialisten zu schaffen. Die Industrie fordert jedoch lautstark immer wieder eine möglichst interdisziplinäre und breite Grundlagenausbildung. Ihre besten Ingenieure beschäftigt sie aber vorwiegend mit Spezialaufgaben, weil es die enorme Informationsflut so verlangt. Auch zeigt sich in der Praxis immer wieder, dass derjenige, der sich als Spezialist behaupten, die besseren Chancen der Einstellung hat. Die Antwort auf die Frage, was man unter 'Grundlagen' zu verstehen hat, wird zudem je nach Fachrichtung sehr davon abhängen, ob man einen Entwicklungsleiter oder gar ein Vorstandmitglied befragt. Hinzu kommt, dass das, was heute noch zu den allgemeinen Grundlagen zählt, morgen nur noch für ein Spezialgebiet Bedeutung haben kann oder ganz überflüssig geworden ist. Der Transistor hat z.B. die Elektronenröhre fast völlig verdrängt, während der Quecksilberdampf-Gleichrichter nicht einmal mehr im Sachverzeichnis eines Lehrbuches zu finden ist. Dafür zählen Programmiersprachen - vor nicht allzu vielen Jahren noch als Pflichtfach unbekannt - in wohl allen technischen Disziplinen als Grundlagenfach.

Eigentlich sind sich alle darüber einig, dass die notwendigen Entscheidungen zu den Problemen der Zukunft nicht allein durch Spezialistentteams getroffen werden können, noch zudem, wenn sich diese in getrennten und oft polarisierten Lagern gegenüberstehen. Falsch wäre jedoch in dieser Situation der Ruf nach einem Generalisten. Wir benötigen vielmehr einen Ingenieuren mit übergreifendem Systemdenken; er muss integrierend denken und handeln können und fähig sein, eine Gesamtanalyse zu treffen. DIETER ALTENPOHL fordert dafür einen Integralisten, der die Methoden und Arbeitsweisen des Spezialisten aus eigener Erfahrung als ehemaliger erfolgreicher Spezialist kennt. Dieser Integralist muss verstehen, die Arbeitsergebnisse eines Spezialistentteams zusammenzufassen und daraus allgemeine übergeordnete Erkenntnisse gewinnen können. Ein Generalist hat dagegen einen Ueberblick über relativ viele Disziplinen, besitzt aber keine eigene Erfahrung mit und in den Methoden der Spezialwissenschaften. Doch die Wandlung vom Spezialisten zum
Integralisten kann nur auf dem Boden geistiger Souveränität ge­deihen, verlangt also eine gediegene Allgemeinbildung.

Unsere Hochschulen wären allerdings überfordert, falls sie auch noch eine Allgemeinbildung vermitteln sollten; das ist die Aufgaben der Schulen im Sekundarbereich, der Oberschulen und Gymnasien. Dort wird aber mehr und mehr eine berufsbezogene Ausbildung als Bildung ausgegeben und angeboten. Bildung ist dagegen zweckfrei; sie verpflichtet zu Takt und Anstand und ermöglicht das schöpferische Spiel des Geistes, das notwendig ist, um zu einem kreativen und innovativen Denken und Handeln zu gelangen. Gleichzeitig gilt es zu verhindern, dass unser technischer Nachwuchs an der Notwendigkeit des Erkennens der physikalischen Zusammenhänge vorbei geführt wird und die Fähigkeit verloren geht, aus übergeordneter Sicht mit Blick auf das Ganze die Bedeutung eines Problems richtig zu erfassen und zu beurteilen. Erst ein Blick von oben lässt erkennen, dass Wassergräben nur in Längsrichtung verbinden; in Querrichtung trennen sie!

Jede Einengung des Horizonts ist ferner meist von einem Motiva­tionsverlust begleitet, was schliesslich dazu führen kann, dass unsere zukünftigen Ingenieure mehr programmiert als ausgebildet werden. Ein solcher Ingenieur wird lediglich als informierter Funktionierer oder als funktionierender Funktionär wie ein lebender Automat Befehlscode sinnvoll aneinanderreihen können, im Glauben, dass auch unser Leben allein einer programmierbaren Ordnung der Logik zu gehorchen hat. Zum Menschen gehört aber auch eine gewisse kreative Unordnung, die keiner Logik folgt. Der Taschenrechner ist jedenfalls kein Ersatz für das Gehirn und das Gewissen und auch Mikroprozessor oder Mikrocomputer können nicht aus einer braunen Rosskastanie ein kastanienbraunes Ross machen.

Ausbildung öffnet zwar das Fenster zur Welt, Bildung bestimmt jedoch, wieviel und was das geöffnete Fenster erkennen lässt. Nach NITZSCHE beginnt Bildung 'erst in einer Luftschicht, die hoch über der Welt des Existenzkampfes lagert'. Eine zukunftsgerechte Ingenieurausbildung darf daher nicht an der Schwelle blossen Wissens halmachen. PLATO hat das in seinem berühmten Höhlengleichnis als 'Schein des Seins' eingestuft. Der Ingenieur von morgen muss befähigt sein, zur Stufe des verantwortungsbewussten 'Sein des Seins' zu gelangen.

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Theme 2. Innovation Centres

a. Barriers to innovation and entrepreneurship
b. Establishment, aims and effect of innovation centres
c. Founding a New Technology Based Firm (NTBF); personal experiences and case histories
d. The management of innovation
e. Innovation and design practice
f. Social attitudes and innovation

Chairmen: W.K. Bolton (Great Britain) and W.A. Koumans (the Netherlands)
Rapporteurs: G. Hayward (Great Britain) and M. Healy (Great Britain)
THE FURTHER DEVELOPMENT OF INNOVATION CENTRES IN AND OUTSIDE THE USA

Dr. George Hayward
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ABSTRACT

The paper seeks to explore the growth of innovation centres both in the USA and in Europe and is an extension of the writer's previous paper in which he discussed the Innovation Centres at:

1. Massachusetts Institute of Technology
2. Carnegie-Mellon
3. Oregon
4. Utah

The number of Centres has now increased to ten and it is hoped to give details of all the various centres in the paper. Other Centres are in operation in Europe and a number have started up in the United Kingdom.

The paper will look at the qualities required for Directors of such centres and examine the operation of the Centres under the following headings:

- Organisation structures
- Links with Industry
- Funding
- Student Involvement
- Method of evaluating inventions
- Current activities of the Centres
- Criteria for investment in a project
- Sources of ideas (Universities, industry, lone inventors)

From an analysis of the Centres in operation it is hoped to develop a model suitable for engineering schools in Europe aided by Business Schools, and to determine how best students can work within such Innovation Centres.
THE CAMBRIDGE SCIENCE PARK

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ABSTRACT

In view of the current interest in science parks it is appropriate to review the ten years of experience available from the Cambridge Science Park.

High technology has presented a new opportunity for universities to extend their interest from research towards the product and its manufacture. The science park is seen as a particularly appropriate response to this opportunity.

The paper describes the background to the Cambridge Science Park and the factors which were important to its establishment. The primary objective of the park is discussed and some details given on its specification and location.

Phase 1 of the development was completed in 1981. It involved 22 science-based companies of which almost half were of Cambridge origin. The same multi-company approach is being followed in Phase 3.

Phase 2 which is due for completion by 1983 involves one major company which is centreing its presently distributed activities on the Science Park in a major laboratory.

The Science Park has made a significant contribution to the entrepreneur high-technology infrastructure in Cambridge which is now the basis of a major expansion of science-based companies in the area.

1. INTRODUCTION

There has been quite a dramatic increase in the number of science parks in the UK, some 15 having been announced over the past year (ref. 1). There is also an active interest in a number of European countries where similar enterprises have been set up or are under serious consideration.

It is therefore timely to review the experience with the first of the British Science Parks to be linked with a major academic institution, namely the Cambridge Science Park.

a) The National Setting. The increasing recognition of 'High Technology' as an area in its own right has opened up new horizons for universities in that they can become involved in product development in a more direct way than previously.
One response in the UK has been the setting up of University Industry Liaison Programmes to exploit the fruits of university research and to provide a consultancy service to industry. This initiative, though important, does not grasp the real opportunity of the 'High Technology' area, namely that the university contribution is extended over a wider range of the research, development and production spectrum than before (see Fig. 1).

It is here that the science park is such an appropriate vehicle for the exploitation of 'High Technology'. It allows the facilities to be established for product development and manufacture in close proximity to high technology sources. It is no longer a matter of consultancy advice or research work at a distance but allows direct links to be built up across the entire product development spectrum of Fig. 1.

It was thus appropriate that the British Government in the late 1960's should issue a call to universities to relate more directly to the growing 'High Technology' industry.

b) The Local Setting. The Cambridge response to this government call was to appoint a Senior Committee under the Chairmanship of Sir Nevill Mott (the then Cavendish Professor of Experimental Physics) to consider the local opportunities. This Committee recommended that some additional 'science-based industry' be established close to Cambridge. In addition to being a response to the government initiative the proposal was seen as a way of capitalising on the vast

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**Fig. 1. High technology activity spectrum.**
scientific and technical resource already available in the area through the University Departments and local science-based organisations.

The size and quality of the local scientific and technical community was an important environmental factor. It meant that scientists, engineers and technicians were readily available, that local banks were experienced at financing science-based ventures and that goodwill and general support were all around.

Whilst the setting was right in the ways described above for the establishment of a 'Science Park' the final ingredient of a sponsor had to be found. The collegiate system at Cambridge provides a special opportunity for initiatives to be taken on a commercial basis within a university setting. Thus it was to be expected that one of the colleges rather than the University as a whole would take on the role of sponsor.

Trinity College responded and were able to meet all the requirements for a rapid implementation of the Science Park proposal. They felt a personal commitment to the project because they appreciated its importance both at a national and local level. There was also a tradition within the college for its graduates to be involved in the setting up of science-based companies in the area.

In addition to a positive and entrepreneurial attitude the college brought to the proposal the essential ingredients of a site and a management and finance resource.

The college owned a 140 acre block of land in Cambridge which had remained unused for over 20 years. It had been a marshalling yard for tanks during the Second World War and was in consequence expensive to restore to agricultural use. The Science Park proposal represented a good and financially attractive use for this land.

The college too was well able to manage such an initiative. It has assets in the form of property, land and funds which in size would rival those of a large company and they, therefore, had developed appropriate administrative resources and commercial expertise to handle without difficulty the setting up of a Science Park. In the college Senior Bursar there was a person who combined a scientific background with commercial skills who could drive the scheme through. No special administration was set up but it has been important that the Bursar, the land agents and the architects have remained unchanged since the Park was first begun ten years ago.

On the financial side the college has resources of its own and to date has committed about £2 M on roads, services, buildings, parking and landscaping. No government or other grants have been received, the whole enterprise being operated as a commercial venture. This emphasis has been important in terms of the commercial reality it has provided.

All these factors coming together in the context of a high technology infrastructure in and around the Cambridge area provided a sound base for the enterprise and contributed to its steady growth.
a) The Objective and Specification. Although Science Parks have the common features of science-based industry and a landscaped site there are many differences between them. Not the least among these is the expectation of what a science park will accomplish.

The Cambridge experience suggests that whilst there are many secondary objectives the primary purpose of a science park should be the establishment and steady growth of commercially viable science-based companies. This focus on company growth is an important one and enables other objectives to be kept in perspective. It is also simple, straightforward and easily measured. It brings an important entrepreneurial dimension to the enterprise in which companies encourage and support each other in a common objective.

In order to ensure that the right kind of activity came to the Science Park a specification was agreed between Trinity College and the Cambridgeshire County Council which limited its use to:

i. Scientific research associated with industrial production.
ii. Light industrial production of a kind which is dependent on regular consultation with local scientific sources.

Companies in both these categories have come to the Science Park and this measure of control has worked well. No limit of course was put on the area of scientific activity and current interests include contract research in physics and engineering, veterinary pharmaceuticals and vaccines, the production of ultra-thin metal foil electron-beam technology, laser systems and glass-fibre optics.

The Park environment has been the result of careful planning in terms of landscaping and type of buildings erected. Building density is limited to about 1 sq m of building to 6 sq m of ground compared with the more usual 1 to 2 ratio for industrial sites in the UK. Figure 2 shows the layout of the park and its three phases of development. A 'lake and glade' landscaping pattern is used in phases 1 and 3.

The buildings are generally steel framed with some variation of external cladding between buildings to give a more pleasing overall appearance to the site and avoid too much uniformity. The ground floor slab is designed to support a load of 20 kN/m² and the buildings are designed to allow extension upwards to give a clear height of 6.0 m or an extra floor. Extension outwards is also straightforward and space is allowed around each building for 30% to 100% extension. Four companies have so far taken advantage of this capability. The building planning grid goes down to 600 X 600 mm making for flexibility in the internal layout. A typical division of areas is 25% office, 25% laboratory and 50% manufacturing.

Although two companies have chosen to construct their own buildings the more usual practice is for Trinity College to provide the building to the company's requirement and then lease the premises
Fig. 2. Cambridge Science Park lay-out.

Fig. 3. Cambridge Science Park location.
for a 20 year period, with rent reviews every 5 years. Rents are negotiable but not subsidised. The special situation of new companies is recognised and starter units of 1300 to 3000 sq feet are available on 3 year leases.

b) Location. The Science Park is situated on the North East side of Cambridge. As Figure 3 shows it is bounded by a new motorway network which gives excellent road communications to London and the North.

The distance of 2 miles from the main college and department complex in the centre of Cambridge has probably deterred some of the small new companies that require close day-to-day access to major departments. Equally for those companies that do not require such proximity there are less expensive factory units available 5 miles outside Cambridge.

The Science Park has thus been in a competitive situation. In consequence its first clients were companies at their second stage of growth who were seeking larger premises. As the Park became established and small units were constructed new firms began to move in and a better balance of companies was achieved.

c) Phase 1, 1969-1981. The Mott Report referred to earlier was published in October 1969. Outline planning permission for the development of 14 acres, that is 10% of the available site, was sought in April 1970 and granted in October 1971. Detailed discussion on the site layout and building design began. In 1973 detailed permission to commence building was given and the first company Laser-Scan Laboratories Ltd. took up residence in September that year.

The importance of this information on timing is that it took four years from concept to erection of the first building. Once the site was established buildings were added at the rate of one or two per year. In 1975 the area covered by phase 1 was doubled to 28 acres.

Figure 4 shows the number of companies set-up during this phase. The increase in 1979 and 1981 is partly due to the introduction of starter units as can be seen from Figure 5 which shows growth in terms of floor area occupied.

The number of jobs created during this phase totalled about 620; an average of less than 30 per company. These figures are typical of entrepreneur science-based companies in their early stages. The companies that have moved into the Science Park have included several classic cases where University research has resulted in a marketable product. Laser-Scan Laboratories Ltd. is the most notable of these. It was started in 1969 by three researchers from the Cavendish Physics Laboratory who had been working on laser-scanning methods for analysing photographs of automatic particle tracks. The commercial application of this equipment, developed as a research tool, came with its use in the analysis of maps which could thus be digitised and recorded on tape. This company is now well-established.
Fig. 4. Company growth rate.

Fig. 5. Building area growth rate.
and in recognition of its links with the Cavendish Laboratory has recently financed a 5-year Research Fellowship there.

Of the 22 companies included under phase 1 almost half originated in Cambridge from work in the university; in circumstances similar to Laser-Scan. The only other major classification by company is those which are branches of large national or international organisations. Here the Cambridge scientific environment would appear to be the chief attraction and the Science Park is a convenient way for them to be part of it. In fact the two largest companies LKB Biochem Ltd. and Cambridge Consultants Ltd. although now subsidiaries of Swedish and American parents, respectively, were originally British companies. Cambridge Consultants for example was set-up in 1960 by a group of Cambridge graduates but was taken over by Arthur D. Little in 1972.

d) Phase 2, 1979-1983. A further 28 acres was approved in 1979 and construction is now well-advanced on a major laboratory for the Napp Pharmaceutical Group who also occupy 3 starter units in phase 1 as a temporary base. Due for completion in 1983 the phase 2 building will provide 116,000 sq ft. It will house all the activities of the group including research manufacturing and marketing at present spread over various locations from Watford to Aberdeen. Employment will be provided for 250 people.

This development represents an alternative to the multi-company approach of phase 1. It is, however, unlikely that a single company of this size would be prepared to move onto a Science Park until it had been established and reached a certain level of maturity. It is also undesirable in the early stages since it would not provide the same spur and example as the multi-company approach for the would-be scientific and technological entrepreneur.

e) Phase 3, 1982 onwards. In order to continue the development of the smaller science-based companies some 28 acres were released for development earlier this year. This brings the total area now released to 82 acres, or nearly 60% of the land available.

Two companies plan to move in later this year and proposals are under consideration for starter units with a central administration facility using an Innovation Centre approach.

3. CONCLUSION

The Cambridge Science Park has made an important contribution to the entrepreneur climate in the area. It demonstrated to the academic community that science-based products and ideas could be successfully exploited in the hard commercial world.

The value of this contribution is far beyond the size of the Park or the number of companies it now contains. It began what one National newspaper has referred to as the 'Cambridge Phenomenon' (ref. 2).
Together with a number of other local initiatives a remarkable growth of new science-based companies is taking place. The Science Park should thus be seen as an agency for growth of science-based companies both directly and indirectly and as an important contributor to the development of an entrepreneur orientated high technology infrastructure.

4. ACKNOWLEDGEMENT

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INNOVATION AND EXPLOITATION IN HIGH TECHNOLOGY

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ABSTRACT

The establishment of the Wolfson Microelectronics Institute as a centre for product innovation and exploitation in the field of microelectronics research is described. Strongly coupled to the University of Edinburgh it operates as a small commercial unit contributing to the education of engineers and existing industry with the adoption of the new technologies. As a result of its activities a number of new products have been developed and it has acted as a seed-bed for new high technology companies. This latter role will become of increasing importance in the future.

RESUME

L'article décrit l'établissement du Wolfson Microelectronics Institute comme centre d'innovation et d'exploitation dans le domaine de la recherche microélectronique. L'Institute, qui maintient des liens étroits avec l'Université d'Édimbourg, fonctionne comme entreprise commerciale et offre en même temps qu'une formation technique aux étudiants-ingénieurs, un service de consultation et d'aide pratique à l'industrie écossaise qui affronte les problèmes de la technologie nouvelle. Plusieurs produits nouveaux ont été développés par l'Institute depuis le début des années 70. L'Institute a également joué un rôle actif dans la création de nouvelles compagnies dans le domaine de la microélectronique, et on envisage que cet aspect de l'Institute prendra une importance encore plus marquée à l'avenir.

ZUSAMMENFASSUNG

Im folgenden wird die Gründung und die Bedeutung des Wolfson Microelectronics Institute als Zentrum für innovative Produkte und deren Anwendung auf dem Gebiet der Mikroelektronikforschung erläutert. Das Institut arbeitet eng mit der Universität Edinburgh zusammen und ist ein kleiner, kommerziell ausgerichteter Teil der Universität, der durch die Aufnahme von neuen Technologien zur Ausbildung von Ingenieuren und zur Entwicklung der bestehenden Industrie beiträgt. Die Entwicklung zahlreicher neuer Produkte ist aug die
1. INTRODUCTION

British Academic Institutions have traditionally concentrated their efforts on education and basic research. Their achievements in pure research are well-known and their supply of trained manpower to meet the needs of society has in general terms been adequate although there have been shortcomings in particular areas such as electronic engineering. The relationship of Universities with the rest of society has, however, been at best an arms length one often called 'ivory towers' of learning which are divorced from the needs of the community. This criticism is perhaps borne out by the relative failure of Universities to translate the fruits of the research into innovation in industrial terms. The reasons for this are complex involving such considerations as academic career promotion and more basically the very perception of engineering as an acceptable career opportunity.

It was against this background that a bold plan was conceived some 13 years ago at Edinburgh University, one of the older Universities in Scotland with a strong medical, legal and scientific tradition, to attempt to relate the teaching and research of Electrical Engineering closely with the activities of Industry through the establishment of a Microelectronics Liaison Unit. The original functions of this Unit which later became the Wolfson Microelectronics Institute were:

- To improve the training of engineers in microelectronics through exposure to industrial developments and practice.
- To introduce new microelectronic technology into industry.
- To exploit commercially the research ideas conceived in the University.

The underlying philosophy of the Institute remains unchanged to this day although the techniques used and the style of the work undertaken has evolved over the years. The Institute has achieved a significant level of success in fulfilling its objectives and could be a useful model for similar academically related innovation centres. In this paper the structure and operation of the Institute are described and the conditions which have been necessary for its success are discussed.
2. HISTORY

The Institute gets its name from the Wolfson Foundation which donated a sum of £130,700 in 1969 to the University of Edinburgh to found an Industrial Liaison Unit for microelectronics. In 1976 the present name of Wolfson Microelectronics Institute was adopted and this will be used throughout the paper. Although a grant, the money was accepted on the basis that it should be used to establish an organisation which would be self-sustaining; that is it would not receive recurrent funding from the Foundation, nor if it were to be successful should it require financial support from the University.

In spite of its remit to improve the training of engineers, the Institute was conceived as being self-financing from contracts obtained from industry for technical services rendered and from licences granted to industry for the exploitation of research based products. After the initial start-up period this has been achieved with a steadily increasing sales revenue which today approaches £1.2M.

3. THE STRUCTURE

In order to influence the training of engineers and to exploit research ideas it was necessary for the Institute to be very closely related to the relevant Academic Department, in this case Electrical Engineering. Yet, if it were to be self-supporting it required a high degree of operational independence from normal academic activities. This was achieved by physically locating the Institute building adjacent to those of the Department of Electrical Engineering while retaining management and staff independence. The full-time post of Director was established, with engineering staff reporting directly to him. The responsibilities of the Director are similar to those of a Managing Director of a company with executive responsibility for the running of the 'business'. He is responsible to a Board of highly respected senior industrialists and academics which assists in determining policy for the Institute and acts on behalf of the legal authority of the University. The Head of the Department of Engineering is ex officio chairman of the Wolfson Institute Board and it is in this way that the formal link between the Academic Department and the Institute is brought about. While the Chairman is in a non-executive position the success of the Institute in fulfilling its objectives relies to a large degree on a good working relationship between these two people.

The Institute, therefore, is an independent structure within the University, responsible for its actions directly to the legal authority, the University Court. It relates at a technical level with the Department of Electrical Engineering, employing members of staff as consultants and carries out work with its own full-time staff.
under contract directly with Industry (Figure 1).

In this way the necessary independence from the teaching and research activities of the University is obtained while preserving a sufficiently close technical cooperation to ensure the interchange of ideas.

4. ORGANISATION

The Institute has two major technological thrusts to its activities:

- Integrated circuit component design.
- Microelectronic product development.

These are organised into two groups each responsible to a manager (Figure 2). Financial control is also done locally although the University administration acts as the banker to the Institute, and provides some administration services. Until recently, the Institute employed its own marketing staff but in an attempt to broaden the basis of this activity it established, in conjunction with a group at the Heriot-Watt University, a jointly owned marketing company, INMAP Ltd. All the marketing staff are now employees of this company which provides a keener industrial profile and a degree of flexibility in marketing and sales which is difficult to sustain in a University environment.

The Institute now employs 20 people and has a turnover in excess of £ 400,000 in the financial year 1981/1982. The majority of the staff are professional engineers but the Institute also employs its own technical, secretarial and administration support staff.
5. ACTIVITIES

There has been a concerted effort over a number of years to specialize in providing a design service for custom large-scale integrated (L.S.I.) circuits. This activity now contributes more than half the turnover. The Institute is widely recognized as a 'Centre of Excellence' for such designs, particularly those making use of charge coupled device (CCD) technologies. With developments of semiconductor technology the Institute is now involved in designing very large scale integrated (VLSI) circuits which provide the possibility of implementing complete electronic systems on a single chip. Both of these technologies have strong research bases in the Department of Electrical Engineering and for VLSI design where software tools are of increasing importance the expertise resident in the Department of Computer Science will be involved.

Normally, the semiconductor industry demands large-volume runs as a pre-requisite of diverting its engineering design effort on the custom-designed circuits. These circumstances have allowed Wolfson to perform a significant design role for customers with smaller volume runs requiring custom L.S.I. circuits for adding-value to innovative products. The catalogue of L.S.I. circuits produced by Wolfson includes correlators for industrial flow measurement, the counter display for the Moore & Wright electronic micrometer, programmable and adaptive transversal filters for sonar signal processing, pattern recognition and line equalisation, and a telephone chip for interfacing handsets to a P.A.B.X.

The facilities within the Institute for circuit design of silicon chips are both advanced and comprehensive. One of the main design
tools which was developed jointly by the Institute and the Depart­
ment of Computer Science is the GAELIC Computer Aided Design suite.
This suite of programs which contains a unique degree of automation
is now being sold worldwide by Compeda Ltd., a subsidiary of the
British Technology Group (BTG). GAELIC has also been adopted by the
Science and Engineering Research Council (SERC) for the support of
integrated circuit-design research and teaching throughout the
British universities.

Maskmaking and wafer fabrication are normally subcontracted to
the semiconductor industry to ensure that the necessary production
volumes can be obtained (Figure 3). A number of companies both in UK

and USA provide the range of technologies which are required. How­
ever, SERC has recently enhanced through £ 1.2M funding, the semi­
conductor fabrication facilities in the Department of Electrical
Engineering to form the Edinburgh Microfabrication Facility (EMF).
The EMF is capable of manufacturing small quantities of specialist
devices for academic researchers and is widely used to support M.Sc.
courses in I.C. design. It is also available to the Institute for
development and prototype work; once again bringing together research
and industrially oriented activities. This facility which it is
expected will be further enhanced by investment of £ 1.8M to under­
take VLSI research will form a unique base in Britain for the educa­
tion and training of graduates in microelectronics for the 1980s.
The second group in the Institute are concerned with product development involving custom or semicustom chips as well as standard components such as microcomputers. They also provide a range of consultancy services to industry often not involved in electronics. Products which have emerged directly from academic research include flow meters, a frequency agile synchronisation unit, a diving communications system and a number of integrated circuits which are being commercially exploited.

Other products such as the micrometer and a heart rate monitor have involved participation by academics but have arisen out of customers' enquiries.

In the area of consultancy services the Institute is working in conjunction with both the local authority and the nationally responsible Department of Industry. The latter encourages industry to use microelectronics through a grant to consultants (MAPCON) such as the Institute, to carry out a feasibility study for a particular application. With the local Lothian Regional support, the Institute goes further than this, actually ferreting out companies and helping them identify opportunities (Figure 4). The interaction with the

![Diagram](image_url)

**Fig. 4. MICROPROCESSOR APPLICATIONS IN THE LOTHIANS**

Support at every phase

academic consultants can be most valuable in this instance as the range of companies encountered is very broad and the knowledge re-
quired to give them assistance would be too great for a small organisation such as the Institute. As mentioned earlier the marketing company INMAP Ltd. has been formed primarily to assist the more traditional companies to take advantage of microelectronic technologies. In addition to marketing the services provided by the Institute it is carrying out a major programme creating an awareness of microelectronics in Scottish Industry and undertaking technical assessments of their potential developments. The programme is supported by both government funds through the Department of Industry and the Scottish Development Agency and private investment through the Royal Bank of Scotland.

6. SPIN-OFF COMPANIES

As aspect of the Institute not yet mentioned is that it acts as a seed-bed of new companies. Working at the interface of industry and university, the staff are in constant contact with new ideas and considerations of commercially exploiting them. It is not surprising, therefore, that from time to time a group will break away to set up their own company (Figure 5). Examples of these are Silicon Microsystems Ltd. and Denyer Walmsley (Microelectronics) Ltd. Both of these companies are offering integrated circuit design services and have developed their own specialities in this field. Lattice Logic Ltd., an even more recent start-up, has developed out of the Computer Science Department and is providing new software tools for i.c. design.

7. OPPORTUNITIES FOR THE FUTURE

As the technology evolves the focus of the Institute's work must change to keep pace with the new research ideas and the demands of industry. Clearly VLSI design and circuit fabrication must be a key part of any future strategy. The important link to the commercial world is through the application of this technology and it is in the field of information processing and communications that major opportunities have been identified.

The field of Information Technology (IT) is, however, vast and it would be impossible for the Institute on its own to contribute in more than a miniscule way. A strategy, involving the whole University of Edinburgh is, therefore, being developed under the guidance of a new senior committee involving both academics from the Departments of Artificial Intelligence (AI), Computer Science (CS) and Electrical Engineering (EE), industrialists from relevant Industries, the Regional Computing Centre (ERCC) and the Wolfson Institute. The strategy will obviously involve the development of appropriate academic courses to produce skilled manpower, but it will primarily be concerned with the coordination and industrial
Fig. 5. MODEL FOR THE 80's: SPIN-OFF IT COMPANIES
exploitation of research in this area. At Edinburgh the existing work, which includes the development of design tools in Computer Science, their use in designing VLSI circuits in Electrical Engineering and the investigation of knowledge based (expert) systems in Artificial Intelligence, provides a unique base from which to develop new commercial products and which provide the basis for spin-off IT companies. Clearly this will require larger initiatives than are possible from Edinburgh. Already the EEC and the British government are directing considerable resources to develop European programmes in IT which it is anticipated will involve the research and development capability in the University of Edinburgh.
ABSTRACT

A survey of companies which have been spin-off from Chalmers University of Technology, Göteborg, Sweden, has been made and compared to patent activity at Chalmers. The results are compared to similar studies of spin-off companies in Boston and California. We find spin-off rates between those reported for California and those which can be deduced for MIT. The situation with regard to spin-off companies and spin-off founders offers many similarities to the situation at MIT and Stanford. However, on the average the companies from Chalmers are smaller and newer.

RESUME

Une revue sur les spin-off companies de Chalmers Université de Technologie en Göteborg, Suède, a été effectué et comparé à une inventaire sur les activités de brevets à Chalmers. Ensuite les résultats ont été à des semblables études sur les spin-off companies à Boston et en Californie. Nous trouvons des 'spin-off frequences' entre ces rapporté de Californie et ces qui peut-être calculé à MIT. La situation à l'égard de spin-off compagnies et leur fondateurs présent beaucoup de similarité avec la situation à MIT et à Stanford. Cependant, en moyenne les compagnies de Chalmers sont plus petits et plus récent.

ZUSAMMENFASSUNG

1. INTRODUCTION

The role of technical universities in the innovation process is often discussed. As is well known new ideas for products or services stemming from research laboratories or from the outside are difficult to evaluate because many problems unknown at the outset may turn up during the development phase, or later. Therefore, it has become desirable and even necessary to follow up good ideas rather far into commercialization to obtain a solid enough basis for evaluation. This means that universities must be ready and willing to support the founding of new enterprises to commercialize new ideas until industry is willing to take over. This paper will describe new enterprises based on ideas from Chalmers University of Technology and started by staff or students from Chalmers.

2. INFORMATION GATHERING

We compiled a catalogue of spin-off companies and through telephone interviews we determined the relation of each company to Chalmers at its founding (to determine if the company really matches out definition of a spin-off company), the business of the company, and the background and qualifications of the founder or founders. Also, we were interested in the size of the company and its legal form (private company, partnership or corporation).

Some years previously, in 1978, we made a survey of patent activities at Chalmers by sending each professor a short letter of enquiry. This produced a rather complete picture of who has applied for patents and whether they have been approved by the patent office, and whether they have been exploited through licensing, etc. We compare this information with the spin-off information in the following.

3. RESULTS

a. The companies

In order to be classified as a spin-off company from Chalmers three criteria had to be met. First, the company founder or founders had to come from Chalmers (faculty, staff or student). Second, the activity of the company had to be based on a technical idea generated in the Chalmers environment. Third, the transfer from Chalmers to the company had to be direct rather than via an intermediate employment somewhere else. In all, we have found 38 companies that fulfill these criteria. They employ a total of about 235 people today. At the time of founding eight of the companies were private companies ('enskild firma'), five were partnerships ('handelsbolag'), 22 were corporations under Swedish law, and three were non-profit organizations. The number of companies founded each year is shown in Figure 1.
Fig. 1. Number of spin-off companies founded each year.

Fig. 2. Patent and spin-off activity of different academic departments.
Roberts (1970) indicated that companies founded by one man had a lower success rate than those founded by two or more men. We do not know how many companies have disappeared over the years, and we cannot check this statement directly. However, we can look at the companies which have succeeded in growing to an employment of five or more. There are presently ten companies which have at least five man-years employment per year. Of these, eight were founded by one man, five on a part-time basis and three on a full-time basis. The other two spin-off companies were founded by three men each, one company on a part-time basis and one on a full-time basis. This seems compatible with Robert's results, but the sample size is too small to draw hard conclusions.

The founders of the spin-off companies come from five schools at the University. As Figure 2 shows, the distribution is not even over the different departments (each department is headed by a professor), and two departments, Electron Physics III and Nuclear Chemistry, are the most active in founding new companies. This may be due to the attitudes of the professors involved, and to a 'me too' effect in the two groups.

Finally, Cooper (1973) indicates that spin-off companies from universities tend to provide services more than products. If we include research and development, testing, consulting and computer programming under services, 26 of the 38 companies fall into this group. The other 12 companies manufacture standard and custom products.

b. The founders

According to Roberts (1968, 1970) and Roberts and Wainer (1968) the median age of founders of high technology companies from MIT is 31 or 32 years. This is similar to results of other studies as reported by Cooper (1973). The median age of the founders of Chalmers spin-off companies is 32 years. The age distribution of the 64 different founders is shown in Figure 3.

Fig. 3. Age distribution of company founders.
According to Roberts (1968, 1970), Roberts and Wainer (1968), Cooper (1973) and Utterback (1974) the education of the founders is rather high, with bachelor's or master's degree being typical. The academic training of the founders of Chalmers spin-off companies is shown in Table I.

TABLE I. Academic degrees of founders (civilingenjör ≈ bachelor or master of science).

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than civilingenjör</td>
<td>12</td>
</tr>
<tr>
<td>Civilingenjör</td>
<td>20</td>
</tr>
<tr>
<td>More than civilingenjör</td>
<td>31</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
</tr>
</tbody>
</table>

c. Patent activity

In the patent survey mentioned previously we found that in all 93 patents have been applied for by Chalmers personnel during their employment at Chalmers. They were generated over a fifteen year period, with increasing frequency during recent years. Figure 2 shows the distribution of the patent activity among the various departments.

Of the 93 patents, about 50 have been successfully licensed to manufacturing companies. About nine of them have been exploited through the inventor's own companies (spin-off companies). This nearly 2/3 exploitation is characteristic for the five engineering schools of the University.

4. DISCUSSION

Many aspects of the spin-off companies from Chalmers University of Technology are very similar to those from MIT or California. However, some differences in the results in addition to the consequences of variations in the definition of spin-off company are worth study. First is the fact that the studies by Roberts and Cooper were carried out in the sixties, while the present material is mostly related to the seventies. The general economic climate has changed considerably during that time. How these changes affect spin-off companies is not so clear, however.

Another difference in the material is related to the history of the institutions involved. Both Stanford and MIT were well established and rather stabilized universities when the studies were carried out. There was time to build up a group of spin-off companies which in turn could mature and take positions as leaders in the process of establishment of new business. This is not the case for Chalmers University of Technology. Chalmers in its present form is little
more than ten or fifteen years old. There has hardly been time to
generate many spin-off companies which were attracted to private
enterprise by previously established spin-off companies. It is hoped
that this will happen in the eighties.

Most of the Chalmers spin-off companies offer services of some
kind. A contributing factor to this situation is that it is often
less capital intensive to provide services than to build up a manu­
facturing machine park. Venture capital from private sources is not
readily available in Sweden. Instead the main sources of capital
open to spin-off companies are government agencies. This is in con­
trast to the situation in the United States.

Finally, what are the incentives to start a spin-off company?
Most often they are a drive to be independent, a need for freedom,
a desire 'to do something', etc. It is not true that the founders
of spin-off companies expect to earn large salaries and get rich in
the short term. The seven company founders who work full-time in
their companies which employ at least five people were questioned
by telephone concerning their incomes from their companies. All of
them were willing to give approximate values of their personal in­
comes when the reason for the enquiry was explained.

These incomes can be compared to nation wide statistics on the
incomes of civilingenjörs in private industry according to age. Of
the seven founders interviewed, only two had incomes a little
greater than the mean incomes of their colleagues in private in­
dustry. The other five founders all had incomes at least 10% lower
than the average for their ages in industry. On the average their
incomes were over 20% lower.

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AN EXPERIMENT IN UNIVERSITY EDUCATION FOR ENTREPRENEURSHIP AND INNOVATION

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ABSTRACT

The design of the Enterprise Centre at University College Dublin as an experiment in educational intervention into the socio-economic processes of entrepreneurship and innovation is described. The conceptual framework chosen to guide the experiment is explained, and the objectives and nature of specific programmes are outlined as well as the directions for future development.

RESUME

Le dessin de le Centre d'Entreprise à University College Dublin, une expérience d'intervention éducational dans le cours socio-économique d'entreprise et d'innovation est présenté. Le modèle qui est choisi pour guider l'expérience est expliqué, et les objectives et nature des cours spécifiques sont indiqué aussi que les directives pour le développement du futur.

ZUSAMMENFASSUNG

Der Entwurf des Unternehmens Zentrums in University College Dublin als ein Experiment von Akademishem Eingriff im Sozial-Ökonomischen Prozess der Entrepreneur und Ingangsetzung neuer Anwendungen und Ideen, wird beschrieben. Die formicrende Konzepte, die für die Leitung dieses Experimentes gewählt wurden, werden erklärt und die Ziele und Enthalt von spezifischen Programmen werden beschrieben, sowohl als die Richtung von zukünftiger Entwürfe.

1. INTRODUCTION

Entrepreneurship is used in this paper in the broad Schumpeterian sense to connote 'new combinations' (Schumpeter, 1961) carried out by an entrepreneur and manifesting themselves as organisational phenomena - the creation of a new venture or the significant recreation of an established venture. Innovation is taken to describe the process of transforming a creative idea into a finished article,
process or system (Whitfield, 1975). The work of The Enterprise Centre at University College Dublin focuses on the managerial and organisational processes of entrepreneurship and innovation as a combined area of application for the managerial technology of a University business school. It is assumed that an opportunity exists for the University to intervene through the activity of such a Centre in the workings of these processes in a manner which promotes and assists in techno-, socio-economic change and development in the community of which the University is a part.

2. A FRAMEWORK FOR EDUCATIONAL INTERVENTION

Entrepreneurship and innovation are complex phenomena. If one sets out to intervene in these processes to produce 'more' or 'better' of either, it is desirable to design the intervention within a reasonably complex concept of the processes. The design of the activity of The Enterprise Centre is based on a paradigm of the entrepreneurial process described in summary fashion below and illustrated in Figure 1.

Much in the manner of Wilken (1979) it is suggested that the critical antecedents of entrepreneurial activity are both economic and socio-cultural. Both categories of antecedent conditions are assumed necessary for the emergence and growth of entrepreneurship. The availability and cost of factors of production, access to markets and the availability of relevant information are factors that fundamentally affect the emergence of entrepreneurial behaviour. Equally, there are underlying socio-cultural variables that determine both the quantity and nature of the entrepreneurial activity that is to be observed in any community. These latter variables include cultural value systems, social structure and stratification, social and technical traditions, attitude systems and the influence of family, education and religion in forming individual and group patterns of behaviour.

Our paradigm suggests that these macro-environmental factors are mediated in their impact on individuals and organisations as they choose to behave entrepreneurially or otherwise by the industrial ecology of a region or local area. In the United States, for example, much has been made of the role of 'incubator companies' in local areas acting as breeding grounds for entrepreneurs which they spin-off into the same local community (Cooper, 1973).

It is also clear that entrepreneurship must have credibility as an activity and as a social role if significant numbers of new ventures are to be encouraged. Local & regional areas can acquire a level of self-sustaining entrepreneurial growth through the demonstration effect of initial successful entrants into independent entrepreneurship. A related element of the local industrial ecology is the existence of support, supply, and advisory services tuned to the needs of new and innovative enterprise. Where the accounting, legal,
Figure 1. A framework for the design of educational intervention in entrepreneurship and innovation.

Antecedents of Entrepreneurial Behaviour

- Economic Variables
  - Availability & Cost of Factors of Reduction
  - Access to Markets
  - Information

- Socio-Cultural Variables
  - Values
  - Social Structure
  - Socio-Technical Tradition
  - Attitudes
  - Social Institutions (Family, Religion, Education)

Regional Ecological Mediating Factors

- Incubator Organisations
- Role Credibility
- Role Models
- Infrastructural supports, supplies, advisory & educational systems
- Communications Infrastructure

Entrepreneurial Actors

- Individuals
  - Independent Entrepreneurs
  - Administrative Entrepreneurs

- Organisations

Entrepreneurial Behaviour

- Formation of New Ventures
- Renewal of Established Ventures
banking, education, research, management consulting and supply services are non-existent or are geared to large mature industry, the prospects for innovation and entrepreneurship are significantly diminished.

These features of the local and regional ecology are, therefore, critical mediating factors which may help to discriminate between entrepreneurially active & inactive areas within one nation or community of nations.

The economic and socio-cultural antecedents of entrepreneurship act through the mediating influence of the local industrial ecology on two classes of entrepreneurial actors - individuals and organisations. Individuals act out an entrepreneurial role by forming new ventures (through the role of independent entrepreneur) or by revitalising or renewing established ventures (through the role of administrative entrepreneur). Organisations behave entrepreneurially through conscious strategic choice of innovative behaviour concerning their resources, products, markets and business definition. It is interesting to note that much of the current debate in strategic management and planning revolves about the issue of designing for organisational innovation and entrepreneurship (Murray, 1982).

The specific behaviour of the entrepreneurial actors takes two forms - the founding of new ventures and the renewal or redirection of established ventures. Both of these behaviours are complex processes acted out over a time period stretching from the occurrence of a stimulus to action through the conceptualisation of the entrepreneurial project, its assessment, its technical and managerial design, its launch and early life until consolidation.

In examining the interacting factors described above, the University educator must ask where are the accessible points of intervention in the system. As we have approached this question from the perspective of a University school of management the following comments are addressed only to the opportunities for intervention open to such a school.

The underlying socio-cultural features of the system are not in any relevant sense accessible and at first glance one might say the same of the economic opportunity variables. However, in so far as economic opportunity is a function of information, the research output of the University can contribute by overcoming information barriers concerning market opportunities. The Enterprise Centre is addressing this possibility by encouraging research in the areas of industry analysis - focusing especially on new and growing industries - and on entrepreneurial opportunity identification (Saunders, 1981; Shields, 1977). The economic opportunity environment is a prime target for intervention by public policy makers, focusing especially on the provision of financial aid and incentives to entrepreneurial behaviour. This form of policy intervention is formulated on the basis of assumptions, theories and hypotheses concerning the relationship between policy interventions and likely entrepreneurial response. Identification and clarification of these relationships may be
significantly helped by the research activity of a University business school acting as an objective and detached observer of the relevant processes. Even if such research contributes only to minor improvement in the design and implementation of industrial development policy, the savings in cost and the improved return on public funds could be very considerable. Currently, The Enterprise Centre is engaged in case-based research on new ventures, funded by the National Board for Science & Technology which is aimed at this specific purpose.

Looking at the local or regional industrial ecological environment for entrepreneurial behaviour the University business school can potentially intervene by affecting some elements of the desirable infrastructure. For example, it seems reasonable to assume that the credibility of entrepreneurship as a career option has not traditionally been high for University graduates. As they leave University to take up employment they are more likely to search out secure employment in larger private-sector organisations or in State organisations. To the extent that a business school chooses to emphasize entrepreneurship and innovation as areas of high priority in the application of management science, it can significantly raise the credibility and perceived value of related managerial roles. The teaching programmes of The Enterprise Centre are fundamentally oriented towards achieving these ends of credibility and perceived value. This is done through curriculum content which investigates the role of enterprise and innovation in economic development, the role of entrepreneurial strategy in enterprise growth and evolution and through coverage of the technical managerial competences and theory related to new venture management and enterprise renewal. It is assumed that through exposure to such curriculum, the graduates of the University business school affect - especially over the long-run - the attitude and value system embedded in the industrial ecology of the University's hinterland.

A University business school can also provide part of the regional industrial ecology by making its research and advisory capability available to new ventures and to ventures pursuing innovative strategies. The mechanisms for doing this are not immediately clear and demand some innovative behaviour of the University. Currently, The Enterprise Centre attempts, on a pilot basis, to provide part of the ecological infrastructure by promoting joint project work between graduate students and local ventures - providing a learning experience for the students and a practical problem-solving and managerial technology-transfer experience for the individual venture.

The business school can also intervene by offering an educational service through non-degree programmes for managers of new ventures and managers charged with the development and implementation of entrepreneurial strategy in established enterprise. Such programmes focus on assisting entrepreneurial actors - individuals and organisations - to manage the processes of new venture formation and enterprise renewal.
Direct intervention in the latter processes of the entrepreneurial system outlined in Figure 1 is, therefore, possible. The programmes designed to undertake the task must of necessity be very specific in their curriculum and very application-oriented in their transfer of managerial technology.

3. THE TEACHING PROGRAMMES OF THE ENTERPRISE CENTRE

The elements of the educational and research programme of The Enterprise Centre have been described above in the context of their intervention objectives. One further underlying principle of design should be explained to clarify the intended role of the Centre. Because of its location in a University business school it is considered appropriate to focus on entrepreneurship and innovation of a knowledge-intensive nature. Knowledge-intensive industry should logically be the principal sector of employment for university graduates and should provide the bulk of the University's organisational clientele. The match of resources, interests and culture is greatest between the University and these sectors of industry. In addition, it is the knowledge-intensive industries that have emerged as the leading sectors of the new industrial revolution and as those in which growth and development is most vitally required for a small open economy with limited natural resources such as Ireland. Because of these factors, The Enterprise Centre focuses its work on problems and issues related to knowledge-intensive industry.

The specific programmes - their objectives, strategy and consequences - that have been developed to date are summarised in Table 1.

4. STUDENT PROJECT WORK IN INDUSTRY

A fundamental element of the graduate MBS programme in Enterprise Development has been to match theory-based coursework with project-based fieldwork in an attempt to bridge the gap between theory and application. Project work has two objectives:

(a) For the student: to test, and learn how to apply, theory to the 'live' managerial problems of new ventures and of organisations undergoing, or in need of, renewal.

(b) For the co-operating companies: to absorb some of the managerial technology available in the University through co-operation with the students in their analytical and problem-structuring activity; and to have a significant 'problem' or challenge that they face analysed by the students and a 'solution' developed through the process of interaction and mutual learning.

In addition to the work of students on the MBS programme, other graduate students and especially MBA students have been assisted, with the help of the Industrial Development Authority, to undertake dissertation research on the managerial issues faced by individual
<table>
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<th>Programme</th>
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| Enterprise Development Undergraduate Course   | **Attitude:** to create credibility for, and interest in, an entrepreneurial career.  
Knowledge: to transfer the basic set of theories and concepts concerning the formation of new ventures; entrepreneurship; innovation; creativity and enterprise renewal.  
Skill: to develop skills of creativity and project appraisal through project work. | **Curriculum design involving field work with entrepreneurs; development of an entrepreneurial project; case analysis; extensive reading in related theory and empirical research; lectures and seminars.** | **Young Graduates with deep interest in and considerable commitment to entrepreneurial activity as:**  
- independent entrepreneurs  
- administrative entrepreneurs  
- support agents in banks development agencies, etc. |
| Graduate Course (N.B.S. Degree)               | **As above but at a considerably more advanced theoretical level with special emphasis on the empirical research traditions of the related areas of knowledge.** | **As above, but with greater independence of inquiry demanded of students ... Extensive & Professionally-oriented project work with new and established ventures ... dissertation research. Specific course modules include: New Venture Management; The Enterprising Process; Entrepreneurial Strategy; Consumer & Buyer Behaviour Analysis; Implementing Entrepreneurial Strategy; Corporate Financial Management.** | **Graduate students with advanced training in the theory of entrepreneurship and proven ability to apply this knowledge to the problems of new ventures and ventures undergoing renewal.** |
| Programme for Small New Ventures in Association with the Confederation of Irish Industry | **To transmit specific technical managerial competences related to the management of small ventures to the promoters and senior managers of such ventures.** | **The appropriate knowledge & skill - development curriculum elements are scheduled over five successive Saturdays (9 hours each day) so that owner-managers can attend without detriment to the operational management of their enterprise.** | **Transfer of management technology into professional use in small new ventures in the University's local area.** |
new ventures. This latter programme is implemented by searching for a 'marriage of convenience' between a student's research interests and a researchable problem faced by a new venture.

While this project-work in co-operation with industry is still in its infancy, results to date are encouraging. The administrative demands of organising this work are considerable and significant faculty time is absorbed in the process of setting-up projects, monitoring their progress, and interviewing when necessary to ensure that both parties are learning. This administrative demand becomes the major constraint on expansion and further development for this particular University-industry co-operative venture.

5. RESEARCH PROGRAMMES

In keeping with the design philosophy already outlined for The Enterprise Centre, research work is seen as a key means of intervention into the entrepreneurial and innovative processes, and one to which the resources of a University are especially well suited.

The board strategy of the Centre’s emerging research work is to contribute to policy-making and to venture management effectiveness by pursuing research on three topics:
(a) The process of new venture formation.
(b) The process of new industry emergence and industry restructuring.
(c) The process of enterprise renewal.

Research may be implemented in three ways:
(a) Faculty research.
(b) Graduate student dissertation research.
(c) Funded research, employing full-time research workers based in the business school.

To date, faculty research has focused on establishing areas of research priority and on formulating hypotheses. Dissertation research is confined to the Masters Degree level and is constrained by student time and resources. The attempt in this area is, therefore, to encourage individual research projects in related areas which, when married with many others, form a collage which has a significant contribution to make to the understanding of the theme research topics. The current level of output is of the order of 8-10 theses per year.

Funded research is currently in progress with the support of the National Board for Science & Technology, investigating the process of formation of new, native, knowledge-intensive ventures.

While currently constrained by personnel resources it is envisaged that the research work of the Centre should be its major contribution to the long-run development of the Irish entrepreneurship and innovation systems.
6. FUTURE DIRECTIONS

Future developments of prime concern are envisaged in three areas:

(a) Research: relatively modest investment in this area is seen to unlock very substantial skills and resources, unique to the University, which can produce output with very major leverage potential in the formation of public policy, industrial development strategy and corporate entrepreneurial strategy.

(b) Inter-Faculty Co-operative Programmes: currently under discussion at undergraduate level with the School of Engineering, it is believed that combining bright young students, either undergraduate or graduate, from the schools of management, engineering and science has the potential to significantly affect the future formation of knowledge-intensive and technology-based new ventures by creating at an early stage the vital combination of managerial and technological skills, and the appropriate abilities in venture formation and management.

(c) Adult Education Programmes: targeted at the promoters and senior managers of complex knowledge-intensive new ventures and of established enterprise undergoing, or in need of, renewal with the objective of matching such organisations' need for sophisticated management systems and practices with the advanced capability of the University business school in this same area.

REFERENCES

THE CENTRE FOR INNOVATION DEVELOPMENT (C.I.D.) AT THE ROYAL MELBOURNE INSTITUTE OF TECHNOLOGY

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Australia

1. BACKGROUND

The Royal Melbourne Institute of Technology (RMIT) has a broad educational focus which ranges from apprenticeship training, in its Technical College division, to higher degrees by research, in the Advanced College of the Institute. However, RMIT differs from traditional universities, certainly in Australia, in that even its research is industry focused. It is in this climate that the authors became interested in the idea of establishing an Innovation Centre, almost 3 years ago.

From the outset our view of the purpose of the Centre for Innovation Development (C.I.D.) has been an educational one in its widest sense.

The C.I.D., therefore, has the following prime objectives:

a. To raise the level of innovation/entrepreneurship skills in the institute's graduates.

b. To improve the climate for technical innovation and entrepreneurship in the general community by raising awareness of and increasing competence in the innovation process.

Translating these objectives into action, the C.I.D. carries out four basic and interdependent functions:

a. Teaching Innovation.
b. Innovation Development.
c. Advisory Services.
d. Research.

These functions will be discussed in detail in the following sections.

2. TEACHING INNOVATION

a. Undergraduate innovations course

The authors have, since 1980, been conducting a one semester unit (14 weeks, 2 hours per week) on Innovation, directed at final year engineering undergraduates. The unit is built around a project, re-
quiring students to carry out technical, marketing and financial assessment of innovations proposed by the students themselves. The final outcome, and basis for assessment, is a preliminary business plan. A series of lectures, drawing on experts from throughout the Institute with information immediately relevant to the students project and also giving case studies of 'real-life' technical innovators, is given. The unit has been highly successful judged on either student performance or feed-back provided by students.

b. Teaching the community about innovation

Traditionally Australia's economy has been resources based. Originally, farm exports and more recently mining, have allowed a manufacturing industry to develop which is largely based on import substitution and protected in key manufacturing areas by a high tariff structure. In fact, Australia's relative industrial performance over the last decade has deteriorated, no matter what measure is used. For example, licensing fees going out of Australia have been typically seven times the income generated from such agreements. However, over the last ten years the number of licensing agreements made by Australian firms has halved, suggesting local firms no longer have the technological knowhow to even copy overseas products [A]:

It was only recently that Australian politicians showed any concern for this situation. The slow-down in the resources boom coupled with a dawning of the realisation that employment is mainly dependent on the manufacturing and service sectors, is creating a realisation of the importance of Australia's technology base.

Unfortunately, apart from investment in manufacturing having been unfashionable, a number of government taxation policies act as a positive disincentive to entrepreneurship/innovation in technology. These are:

i. Lack of any form of capital gains tax which encourages mainly speculative, short term investment.

ii. A double-tax penalty on retained earnings of private companies making it difficult for small companies to finance their own growth.

iii. Inappropriate depreciation laws, which discourage modernisation of equipment.

The C.I.D. sees one of its tasks to make whatever contribution possible to raise the entrepreneurial/innovative climate in Australia. At this point the C.I.D. is co-operating with a committee of the Australian government looking at how to improve access to Venture Capital. The C.I.D. will probably organise workshops of bankers and financiers throughout Australia to:
i. Increase awareness and interest in venture capital by the financial community.

ii. Make positive recommendations for government and private industry action on how to improve the availability of venture capital.

Similarly the C.I.D. intends, on a continuing basis, to try to identify market niches where Australian industry could have a comparative advantage and publicise them through seminars, a newsletter, etc.

Although not the subject of this paper it should be mentioned that the C.I.D. is part of a wider activity in improving Australia's Industrial Climate. Complementary activities are found, firstly, in ACTIV (Advisory Centre for Technology In Victoria) whose task it is to improve technological awareness by existing industry; and secondly, CODAT (Centre for Overseas Development And Technology) the purpose of which is to increase interaction in the South-East Asian Region (Australia's natural market) (See Figure 1).

3. INNOVATION DEVELOPMENT

In order to be able to teach effectively about the innovation process it is necessary for a continuing real-life involvement in commercialising products, processes and services.

The C.I.D., therefore, has a major commitment in attracting potential innovations from within and outside the institute, for evaluation, with a view to possible commercialisation. Because of the negative climate for innovation/entrepreneurship already described in section 2.a., there are severe barriers for individual and indeed corporate inventors in having their ideas taken up by Australian industry. The C.I.D., by possibly developing an idea to preproduction stages and by carrying out market evaluation and financial analysis, is looking to remove some of the commercial risks from potentially good ideas, thereby making them more attractive for commercialisation by private industry. In carrying out these tasks the C.I.D. is able to call on the extensive and diverse engineering and business expertise and resources of RMIT. The C.I.D. does not, however, want to become a general clearing house for inventions; rather the objective is to commercialise a small number of ideas to:

a. Allow the C.I.D. to be a catalyst and role-model for community-wide innovation.

b. Provide a sufficient set of diverse projects from which to develop and maintain the C.I.D.'s teaching and research programs.

c. Generate a long-term income through royalties, etc. from successfully commercialised projects to make the C.I.D. selfsupporting.
SPONSORS ADVISORY PANEL
* six-monthly meetings
* membership is sponsors representatives
* provide strategic direction for Centre

MANAGEMENT COMMITTEE
* bi-monthly meetings
* membership:
  - 2 Advisory Panel members
  - 3 Deans
  - 1 RMIT Council member
  - CID Manager
* immediate management control

CENTRE FOR INNOVATION DEVELOPMENT
* staff expertise:
  - business
  - engineering
  - marketing

GOVERNMENT & INDUSTRY
- $ royalties
- fee-for-service
- consultants

RMIT COUNCIL
* authorises the existence of a Centre

RMIT DIRECTOR
* six monthly report

RMIT STAFF
- $ funds responsibility
- $ consultants

Fig. 1. Funding and management control of the centre for innovation development at RMIT.
At the time of writing the paper the C.I.D. is actively investigating projects in:

i. Transport;
ii. Medical electronics;
iii. Passive solar systems;
iv. Transducers;
v. Telecommunications;
vi. Electrical appliances.

It is the intention of the C.I.D. to limit itself to between 10 to 15 major projects a year.

4. ADVISORY ROLE OF C.I.D.

a. Assessing business plans

The C.I.D. will assist government or financial organisations, involved in funding technology based companies, in assessing business proposals, such as submissions for funding support. Involvement in this activity, has two direct benefits:

i. The C.I.D. gains first hand experience of what financial institutions look for in a business plan, expertise which can be fed back directly into the centres other activities.

ii. A major cause of high technology projects being rejected is that the potential financier is not comfortable with that technology. The C.I.D., through access to the wide-ranging expertise of RMIT staff, is able to provide expert, unbiased assessment to help financial organisations overcome any technology gap.

The C.I.D. has already provided Advisory assistance of this type to the Victorian State Government in areas as diverse as:

- Computer Hardware;
- Alternative Energy;
- Food Additives;
- Robotics;
- Fertilizers.

b. Assisting innovators in accessing funding

Government, at Federal and State Level has instituted a wide variety of support programs for inventors, small business and research. Changes to programs are frequent. Added to this is a diverse range of funding approaches by banks and other private funding organisations. It is thus not surprising that an individual seeking
funding support finds difficulty navigating through this labyrinth to the organisation most likely to provide support for his/her project. The C.I.D. is developing a data base about potential funding organisations, which will enable it to advise on potential funding sources.

Further, it is evident from past involvement with individuals seeking funding support from government or private sources that many approaches fail not because the project is unsuitable for support but because the submission made is inappropriate. The C.I.D. will shortly establish a service whereby it will assist in preparing submissions for funding support, from applications for government grants to complete business plans for presentation to venture capitalists. The C.I.D. will not charge unless the application is successful.

c. Assisting staff and students of RMIT

RMIT, through a Patent's Committee, has attempted to provide a vehicle for inventions by both students and staff to be taken from a laboratory stage to commercialisation. However, the concept of a Patent Committee has proven to narrow:

i. Many of the ideas generated within the Institute are not patentable but still have commercial potential; often what should be marketed is not a product but a service.

ii. The nature of a patent committee type approach over emphasises the role of patent protection. No market analysis was carried out before deciding on patenting and follow-up was left to the inventor who generally took the attitude that a patent guaranteed commercial success.

The C.I.D. is providing RMIT's students and staff with a free advisory service on how best to approach the commercialisation of ideas. Indeed, whether an idea is worth proceeding with, where patenting of an invention is warranted to C.I.D. will direct it to the Institute's patent committee. Once patented the C.I.D. will assist in the follow-up necessary to achieve commercialisation.

Additionally, through its various interactions with industry the C.I.D. is able to feed-back to the Institute consultant and applied research work for staff, and projects for students.

5. RESEARCH

Long-term survival and development of any academic activity is dependent on a significant research component. As a Centre of Innovation Development the C.I.D. has a commitment to:
a. Research the fundamental process of innovation to try and identify key success factors for an idea to become a socially and commercially desirable innovation.

b. Monitor world-wide trends in innovation research, corporate trends and government policies and assess their relevance to Australia.

c. Develop mechanisms for better identifying market needs for innovation.

As with all of RMIT's research activities, the C.I.D. will make its research goal specific through co-operative programs with outside organisations, and looking for at least partial funding of its research effort from private industry.

6. ORGANISATION OF THE CENTRE FOR INNOVATION DEVELOPMENT

a. Status within RMIT

The Royal Melbourne Institute of Technology, although receiving all its educational funding from Government, is a non-profit company limited by guarantee. Its 'board of directors', the Institute Council, has established the concept of 'centres' to allow major Institute initiatives to be given a relevant identity. Centres have the same status as an academic department except that their continued existence depends on being self-funding. Figure 1 shows the Centre's currently established by RMIT, including the C.I.D.

b. The C.I.D. itself

Before establishing the C.I.D., the operation and funding of Innovation style organisations was studied extensively. Relating what was learned to Australian conditions lead us to the following conclusions:

i. The nature of innovation means some projects tackled will fail, success must be judged on an aggregate basis.

ii. Returns are long-term, based on equity or royalty participation through successful projects.

iii. It is important that C.I.D. focus on basing itself on the strengths of the Institute.

iv. Because of the lack of venture capital for start-up companies, in Australia, the C.I.D. will need to look to established organisations taking on innovations developed by the centre.

c. C.I.D. start-up funding and organisational structure

The consequence of the above conclusions was that generating self-funding for the C.I.D. would be a long-term target. The centre would
therefore, require a high level of 'untied' base funding and that this support would be sought from industry. The approach taken has been to seek 12 firms as sponsors; each has been asked to contribute $25,000 a year and to make a 5 year commitment.

The C.I.D. differs from most Innovation Centres in that the initial base funding was not sought from government. From our dealings with government organisations in other areas it is our conclusion that:

i. Government funding brings with it (rightly) a high level of monitoring.
ii. Results are expected almost instantly to generate community visibility; public relations becomes a high percentage of the workload.
iii. Political sensitivity makes admission of failure of individual projects difficult; risk taking is an anathema.

The sponsors sought have each been in different sectors, to avoid competitive pressures. In return for sponsorship the C.I.D. has committed itself only to:

i. Give sponsors first refusal on innovations developed by the centre.
ii. Involve sponsors in the activities of the C.I.D., generating possible indirect benefit by being able to observe the innovation process at first hand.

Sponsors provide an advisory panel which meets twice a year to renew overall policy directions of the C.I.D. Short-term accountability is to a bi-monthly management committee which consists of:

i. Two Advisory Panel representatives.
ii. Three Deans (Engineering, Business, Management).
iii. One Institute Council representative.
iv. The C.I.D. Manager.

Figure 2 summarises the C.I.D.'s management and funding structure.

d. C.I.D. target market

The strengths of the Royal Melbourne Institute of Technology, of relevance to innovation, are:

i. A commitment to high technology in teaching programs, applied research and consulting.
ii. A Faculty of Business and a Graduate School of Management with an active interest in the managerial and marketing aspects of technology.
Fig. 2. Centres at RMIT related to C.I.D. activities.

C.I.D.
CENTRE for INNOVATION DEVELOPMENT

M.R.C.
MicroELECTRONICS RESEARCH CENTRE
* fundamental research into microelectronic processing
* major funding from Federal Government as one of 10 "Centres of Excellence in Research".

ACTIV
ADVISORY CENTRE for TECHNOLOGY in VICTORIA
* assisting existing industry to assess and implement new technology
* funded by State Government

ITC
INDUSTRIAL TECHNOLOGY CENTRE
* conduct major applied research for industry
* located on industrial land owned by RMIT
* funded by industry

CODAT
CENTRE for OVERSEAS DEVELOPMENT and TECHNOLOGY
* educational and consultancy assistance for South-East Asian & Pacific countries
* funded by Government contracts
iii. A diversity in the fields of technical expertise of Institute academic staff impossible to achieve outside an educational establishment.

The C.I.D. has, therefore, biased itself towards the high end of the technology spectrum in all of its activities, education, innovation development, advisory services and its own research. This perceived niche for the C.I.D. fortunately corresponds with a community need not at present addressed by any other organisation in Australia. As indicated in Section 2.b. Australia has traditionally been a heavy net importer of technological knowhow, although the educational base of the population is high. When technical ideas have been generated, exploitation has generally required exporting the idea. However, long-term viability of Australia's manufacturing industry depends on world competitiveness. Labour costs, a small domestic market and distance from major world markets are all negative factors. It is, therefore, vital that Australia's industry at least learn to benefit from locally generalised ideas. High technology products have the advantage of maintaining the consequences of the negative effects mentioned above.

e. Generating long-term returns

If the C.I.D. is able to successfully generate commercialised products, the returns sought may be of two types:

i. Through equity participation;

ii. Via royalties.

Equity participation is possible where the products developed result in new businesses. In the Australian context the conditions given in Section 2.b. (particularly taxation on retained earnings) plus the inability of trading in equity, unless the company becomes listed on the stock exchange, reduce the possibility of the C.I.D. becoming involved in start-up ventures. It is anticipated that most of the C.I.D. products will be commercialised by existing companies and, hence, royalty returns are the most likely. A two-tier royalty arrangement will generally be negotiated. Initially the objective is for the C.I.D. to recover real costs for the project plus a defined margin. Once this is achieved the royalty level will be renegotiated.

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ABSTRACT

Since the early 1960's new foreign industries have contributed to the dynamic and successful growth of industry in Ireland. A major thrust of economic policies was the encouragement of foreign based companies to come and locate here. While this was a success, both the IDA and SFADCo have been placing increasing emphasis on initiating and assisting Irish domestic industrial projects. In particular, interest is being focused more and more on the role small business and industry can play in the development of technology based innovative activities to help improve our economic potential. The need to modify the economic and social environment to enable individuals to develop their entrepreneurial skills is a concern of Government, Government Agencies, industrialists, and business man.

Studies show that technological innovation is an important force for economic growth and help us classify innovations into:

(i) Those bringing productivity gains.
(ii) Those representing new contributions to existing products or processes.
(iii) Those leading to creation of completely new industries.

Technology based innovation can have a profound effect on the growth of new industry, the economy and consequently employment. While discussion of economic development acknowledges that economic growth depends on a complex of interrelated factors, emphasis has increasingly shifted to the key role of decision making innovators, particularly in industry to - Entrepreneurs.

This study looks at the entrepreneurial process. It is a pilot study of existing entrepreneurs.

This study will:

(1) Provide more precise knowledge and understanding of entrepreneurship with particular emphasis on the factors associated with enterprise initiation.
(2) Provide baseline information for planning and development of promotional programmes for agencies interested in men of enterprise.
Help formulate the focus of a study of potential entrepreneurs which will assist in the identification of potential entrepreneurs in the two key sectors:
(a) entrepreneurial activity in setting up new ventures;
(b) entrepreneurial activity within state and semi-state bodies.

Help in the planning of curriculum development for entrepreneurial programmes and for specific educational programmes concerned with education for entrepreneurship.

INTRODUCTION

In recent years, most industrialised countries have suffered from economic recessions, high unemployment rates and fluctuations in international trade cycles to a degree not experienced since World War II. This situation, coupled with new social demands, has tended to increase the attention paid by policy makers and political decision makers to the potential role of innovators in helping to overcome present problems and social needs. Particularly interest is being focused more and more often on the role small business can play in this process, both on its particular ability to adapt flexibly to a changing environment, and also on its 'natural' inability to adjust itself to technical change at a rate fast enough to survive. Several countries like Ireland, USA, Canada, Sweden, The Netherlands, and the Federal Republic of Germany have recognised this and are preparing new policy measures to support small firms and more specifically, to support their innovation activities and to improve their innovation capabilities (see OECD; Committee for Scientific and Technological Policy: Innovation in Small and Medium Firms, January 5th 1981; see also Bolton Report HMSO 1971; Boswell 1972; Innovation Centre; IDA; NBST).

While discussion of economic development acknowledges that economic growth depends on a complex of interrelated factors, there has been a tendency to focus on a single key factor as a determinant of economic growth. The most important of these key factors include resources, motives, attitudes, capital and government organization. Increasingly, however, emphasis has shifted to the key-role of decision making innovators; particularly in industry to - Entrepreneurs.

THEORIES OF ENTREPRENEURIAL SUPPLY

Theories of entrepreneurial supply centre around three theoretical perspectives:

(1) Sociological;
(2) Economic;
(3) Psychological.
Interesting enough, the entrepreneur and his unique risk-bearing function were first identified in the early 18th Century by Richard Cantillon an Irishman living in France who also coined the term: entrepreneur. The entrepreneur was seen then as buying services at 'certain' prices with a view to selling their product at 'uncertain' prices in the future. Thus, the entrepreneur was defined as a person who bore uninsurable risk. Over the years the term got a broader meaning emphasizing the bringing together of the factors of production and the provision of continuing management as well as risk-bearing (Schumpeter 1971).

For the economist, the determinants of entrepreneurial performance lie on the demand side, in the structure of economic incentives found in the market environment. While acknowledging that extreme economic inducements or impediments will significantly affect entrepreneurial activity, the psychologist holds that over the normal range of variability of financial incentives, the prime movers for risk-bearing and innovation are certain non-economic, non-materialistic, inner, psychic concerns. The sociologist sees economic incentives as but one part of a larger system of sanctions based on the society's value and status hierarchy, which in it's entirety will determine the extent of entrepreneurial activity. What is called for in looking at entrepreneurial supply is a multi-disciplinary approach to the problem. This is the approach of the present study.

The Entrepreneurial Process - A pilot study of existing entrepreneurs

The present study is concerned with the nature of the entrepreneurial process and the examination of the interaction of social, economic and psychological factors associated with this entrepreneurial decision. Figure 1 summarises the study and the factors that are to be investigated. The study looks at a model of the entrepreneurial process from a multi-factorial perspective, sociological, economic and psychological. The entrepreneurial process is seen in terms of the importance and interaction of three main areas in the decision to initiate a new enterprise:

1. Entrepreneurial Attributes - Figure 2a, 2b.
2. Precipitating Factors - Figure 3a, 3b.
3. Venture/Enterprise Specific Factors - Figure 4a, 4b.

The aim of the study is to help identify or characterise the complex array of factors associated with the entrepreneurial process. In this, the study provides a data base for policy makers in general and in particular for policy makers in those agencies where units in planning and development are centred on entrepreneurial activity. It also provides valuable information for curriculum development programmes for entrepreneurial education and specific inputs to educational programmes for entrepreneurs. The study will:
Figure 1: The entrepreneurial process - venture/enterprise

(ENTREPRENEURIAL ATTRIBUTES)

- TRAITS
- PERSONAL FITNESS AND LIFE-STYLE
- KNOWLEDGE AND EXPERIENCE
- SOCIAL BACKGROUND
- SCHOOL ORIENTATION

(PRECIPITATION FACTORS)

- Job satisfaction
- Work situation
- Dissatisfaction in general
- Life satisfaction
- Opportunity
- Age
- Attitude to starting business
- Social climate for entrepreneurs
- Economic climate
- Initial encouragement

(VENTURE/ENTERPRISE SPECIFIC FACTORS)

- Venture/enterprise evaluation
- Support
- Financial
- Sociopsychological
- Technical

(c) Dr. Joyce O'Connor
Social Research Centre
(i) Provide more precise knowledge and understanding of technological entrepreneurship, with particular emphasis on the factors associated with enterprise initiation.

(ii) Provide baseline information for planning and development of promotional and educational programmes for agencies interested in men of enterprise, e.g., IDA, NBST, Innovation Centre and other semi-state bodies.

(iii) Help formulate the focus of a study of potential entrepreneurs which will:

(iv) Help identify potential entrepreneurs in 2 key sectors:
   (a) entrepreneurial activity in setting up new ventures;
   (b) entrepreneurial activity within state and semi-state bodies.

(v) Help in the planning of curriculum development for entrepreneurial programmes and for specific educational programmes concerned with education for entrepreneurship.

Preparatory phase

In preparation for the pilot study of existing entrepreneurs, a series of interviews was conducted with the relevant technical and financial institutions in order to explore the sources of advice, information and assistance available to entrepreneurs.

Secondly, a small number of 'potential' entrepreneurs were also interviewed to test the model's potential in predicting future entrepreneurial activity.

Thirdly, a series of group discussions with entrepreneurs, internal innovators, and the spouses of entrepreneurs were undertaken. The main objective here was to explore how people viewed the model of the entrepreneurial process and how it related to their own experiences.
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<tr>
<th>Traits</th>
<th>Knowledge and Experience</th>
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<tr>
<td>Need for achievement</td>
<td>Administrative ability</td>
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<td>Willingness to take risks</td>
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<td>Total commitment</td>
<td>Human relations ability</td>
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<td>Ability to organise</td>
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<td>Communication ability</td>
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<td>Leadership ability</td>
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<td>Pre-ownership</td>
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<td>Good use of resources</td>
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<td>Personality</td>
<td>Broad thinking of a generalist</td>
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<tr>
<td>Restraint</td>
<td>Conceptual ability</td>
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<tr>
<td>Competing against self imposed standards</td>
<td>Capacity to learn</td>
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<td>Recognition of own limitations</td>
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<td>Internal locus of control</td>
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<td>Feedback</td>
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<td>Money as a measure</td>
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<td>Tolerance of ambiguity and uncertainty</td>
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<td>Low need for status</td>
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<td>Goal Orientated</td>
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<td>Power affiliation</td>
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<td>Good health</td>
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<td>Mental alertness</td>
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<td>Resistance to stress</td>
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<td>Energy</td>
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<th>School Orientation</th>
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<td>Occupation of parents</td>
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<tr>
<td>Career orientation of parents for children</td>
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</table>
Figure 3.a. Precipitating factors.
1. WORK SITUATION
   - Attitude to Employment [Positive] 
     Career Orientation [Negative] 
     Displacement

2. LIFE SATISFACTION
   - Fulfillment of Personal Goals

3. OPPORTUNITY
   - Recognition
   - Exploitation

4. FAMILY RESPONSIBILITIES
   - Early
   - Middle
   - Late

5. LIFECYCLE STAGE
   - Early
   - Middle
   - Late

6. ATTITUDE TO STARTING NEW BUSINESS
   - Success/Failure Orientation
   - Risk Assessment

7. SOCIAL CLIMATE FOR ENTREPRENEURSHIP
   - Popular attitudes to business as a career
   - Popular perceptions of causes of failure
   - Popular perceptions of consequences of failure
   - Popular attitudes to success

8. ECONOMIC CLIMATE
   - Communication of information/ideas/opportunities re. business
   - National Economic Performance
     (i) Effects on financial institutions
     (ii) Effects on potential venturer
   - Perception of National Economic Performance

9. CREDIBILITY OF THE ACT OF INITIATION
   - Identification with Established Venturer.

10. INITIAL ENCOURAGEMENT
    - Home
    - School
    - Work
    - Significant others
Figure 4.a. Venture/Enterprise specific factors.
VENTURE/ENTERPRISE EVALUATION
- Length of time spent on evaluation
- Commitment of spouse/family
- Information Process
  - Knowledge of business markets
  - Knowledge of sources of finance
  - Knowledge of Technical Services
- Information Seeking
  - Product
  - Supply markets
  - Knowledge of infrastructure finance
  - Knowledge of technical services
- Financial Consideration
  - Equity requirements
  - Personal/family implications of venture initiation
- Lifestyle Considerations
  - Effect on significant relationships
  - Home responsibilities
  - Leisure
- Partnership as relates to above

SOCIO-PSYCHOLOGICAL SUPPORT
- Sources of support
  - Stage in relationship
- Type of involvement
  - Pre-Initiation
  - Initiation
  - Post-Initiation
- Attitude of support fixtures to venture:
  - Social implications
  - Financial implications
  - Personal implications

FINANCIAL SUPPORT
- Sources of support
  - Personal contacts
  - Suppliers credit
  - Customer credit
  - Institutions
- Type of financial institutions assisting in entrepreneurship
- Objectives of relevant financial institutions
- Type and conditions of financial support available
- Application Procedures
  - Approach of staff
  - Information requirements
  - Assistance in proposal preparation
  - Decision-making process
  - Time
- Aftercare
  - Type
  - Extent
  - Duration

TECHNICAL SUPPORT
- Technical support services available
- Methods of information dissemination
- Conditions of individual services support:
  - Type
  - Extent
  - Duration
PILOT STUDY

This study explores the entrepreneurial process as set out in Figure 1. This involved a qualitative pilot of 40 indepth interviews tape-recorded with entrepreneurs from 28 companies. The information was collected using a semi-structured interviewing technique to guide the interviews to ensure the three main themes under investigation were covered. All the taped interviews were typed and a content analysis was undertaken to help validate the above model. The purpose of this is to explore the world of the entrepreneur and relate the research findings to the reality of becoming and being a successful entrepreneur. The study also explored the use of psychological tests for use in predicting potential entrepreneurs. This pilot study provides very useful information on entrepreneurs and fulfills in part the main objectives of the study.

(1) Explore the entrepreneurial process in a group of entrepreneurs.
(2) Test the validity and appropriateness of such a model.
(3) Help formulate the focus of a study of potential entrepreneurs.

BIBLIOGRAPHY


EVERY COMPANY AN INNOVATION CENTRE
A STRATEGY FOR CREATING NEW POTENTIAL PRODUCTS

Prof. Fredy Olsson, Dr. Mogens Myrup Andreasen
Lund University of Technology
Denmark

ABSTRACTS

Strategy and methods for establishing an innovation development programme and for performing the creation of new potential business will be treated. The raw material for this exists inside the company, in its own staff and may be promoted, encouraged and utilized. Experiences from Sweden and Denmark verify the benefit of this procedure.

RÉSUMÉ

La stratégie et les méthodes pour établir un programme pour le développement innovatif et pour former la création de possibilités neuves pour les affaires seraient traités. La base pour cela existe dans la compagnie, dans son personnel et peut être promouvue, encouragée et utilisée. Les expérience de la Suède et du Danemark peuvent vérifier le bénéfice de cette procédure.

ZUSAMMENFASSUNG


1. INITIATING AND PLANNING OF INNOVATION ACTIVITIES FOR NEW BUSINESS DEVELOPMENT

Product innovation can be introduced in either a spontaneous and unconscious way or a more conscious and planned way. One can also talk about regular innovation under normal conditions or forced innovation under threatening conditions. All this can lead to new business and product development projects. However, in the following we will try to point out some possibilities for activating sleeping
innovation capacities in individuals, in companies and in education centres.

a. 4-way strategy and method for finding new product ideas

A broad starting-point for getting product ideas leading to development projects is existing situations which we observe on future situations which we can imagine. Situations give rise to a lot of different requirements and a specific need is another and more specific idea-initiator. Technological knowledge offers us possibilities of new solutions and new product ideas can also be based on new or surplus resources. These facts are used as the basis of a strategy for finding new products and are then combined with instructions and techniques to get a complete method for introducing innovation. See Figure 1.

b. Organizing the discovery of products in a company

Independent of the method it is often necessary in existing companies to make special arrangements for getting opportunities for creating ideas. Some successful and effective procedures which do not disturb the ordinary organization too much are:

- Product finding competitions (from a chosen starting-point, see above) once or twice a year.
- Product finding meetings (from a chosen starting-point) one or half a day every month.
Product finding collective notebook for a special task (starting-point) over a longer period (usually several months) parallel to ordinary work.

Free product finding group, the members are allowed to choose their own starting-point, methods, working hours and places over a long period (e.g. a year) with the use of a limited sum of money.

2. INTRODUCING PRODUCT INNOVATION

It is very important to initiate and then take good care of ideas for new products, and to choose those of them which are suitable for starting a product development project. The policy for the number of coexisting projects, the ranking of them and the rate at which they are carried out are also important. This can be dealt with in modern product planning and product development procedures.

a. Product planning and product development programme

Apart from innovation strategy and policy, the planning and programming activities are:

- To supervise existing products, abandon old ones and take up new products.
- To collect spontaneous product ideas and activate the discovery of products.
- To evaluate product ideas, rank ideas for product development projects and establish a development programme.
- To initiate and control the execution of product development projects.

b. A model for integrated product development

In a modern product origination or development procedure various tasks must be performed simultaneously. These tasks, which are often connected with organization functions include:

- Activities concentrated on market investigation and marketing preparation.
- Activities concentrated on technical development and engineering design.
- Activities concentrated on production studies and manufacturing preparation.
- Activities concentrated on financial and economic management.

Our Product Origination or integrated Product Development procedure starts from a material requirement and ends when we have obtained a product accepted by users. The total procedure from requirement to accepted product can be divided into stages depending on
successively reached sub-goals, where essential decisions are for example to be made about:

- Which type of product is competitive to solve the need?
- Which are the best principles for the product?
- Is the primary, functioning product acceptable?
- Is the product suitable and ready for regular use, manufacture and sale?
- Is the product as finally introduced accepted by users?

In this way the procedure consists of four activity-types and five stages and could be combined in a block-model (see Figure 2).

3. IMPLEMENTATION, EXPERIENCES AND FUTURE UTILIZATION

The strategies, methods and procedures described above have been used:

- for product finding in existing companies (5 cases);
- for product development in an existing, big company;
- for new education of innovators, designers and engineers (2 schools);
- for product finding and product development in one innovation centre;
- for initiating and starting up new companies (2 in the last year);

during the five last years in Sweden. The results seem to be adequate and further use is now being considered.

In Denmark the need for an easily understood, integrated product development strategy has also been recognized, leading to a cooperative research project between the Institute of Technology, Lund and the Technical University of Denmark. The established results are now used in product finding and development in existing companies and one engineering school.

4. CONCLUSION

The qualities of integration and of easily being grasped are very important attributes of the strategy presented. The problem of creating good business is often solved in the areas between the activity areas of marketing, design, production and finance. The concepts, procedures and tools connected in our way of tackling the problems of innovation have shown their value in practice.
Figure 2.
ABSTRACT

A number of small companies have been established during the last 5-6 years as spin-off from the Technical University of Denmark. The entrepreneurs based their business on know-how which they picked up and developed during active participation in university research projects.

In this paper we shall look at the special conditions which led to the formation of some of these new companies, and we shall try to draw some conclusions about the kind of research and education environment which is most stimulating for entrepreneurship.

RESUME

Un nombre de petits firmes ont été établis pendant les dernières 5-6 années comme spin-off de l'École des Hautes Études Techniques du Danemark. Les entrepreneurs ont fondé leur affaires sur know-how gagné et développé pendant la participation active aux projects de recherches scientifiques.

Dans cet article nous allons considérer les conditions spéciales menant à la fondation de certains de ces firmes nouvëls, et nous allons essayer de faire des conclusions au sujet du milieu de recherche et d'éducation le plus stimulant pour la fondation.

ZUSAMMENFASSUNG

Eine Anzahl von kleinen Firmen sind während der letzten 5-6 Jahre als Spin-off von der Dänischen Technischen Hochschule etabliert worden. Die Unternehmer haben ihre Geschäfte auf know-how gegründet, das sie unter tätiger Teilnahme an Universitätsforschungsprojekte aufgenommen und entwickelt haben.

In diesem Artikel werden wir uns den speziellen Bedingungen ansehen, die zu der Bildung von einigen von diesen neuen Firmen geführt haben, und wir werden versuchen einige Konklusionen zu ziehen, welche Forschungs- und Ausbildingsmilieu die am meisten stimulierend für die Unternehmung sei.
It has become kind of a myth that people with a long academic education neither have the ability nor the drive to develop new business by forming their own company. They get jobs as civil servants in public service organisations or become employed by big private companies where they can make use of their educational background and follow a traditional career by climbing the organisation ladder.

Fortunately, the true picture looks slightly different, in particular for those with an engineering background. It is still possible to start and survive in the small business world provided you have ideas and professional skill, a sound feeling of market needs, a strong will to work for results and a bit of luck.

A number of small science based companies have been established during the last 5-6 years as spin-offs from the Technical University of Denmark (DTH). In this paper we shall look at the special conditions which led to the formation of some of these new companies, and we shall try to draw some conclusions about the kind of research and education environment which is most stimulating for entrepreneurship.

1. TRANSFER OF IDEAS

The characteristic profile of a technical university is a mixture of basic and applied research and development. About half of the current research projects at DTH are considered as basic research, i.e. not dedicated any particular application. Other projects are conducted in collaboration with international organisations, public service organisations, ministries, or private industry, and they are in a more direct way oriented towards specific problems. Their aim is to develop better technical solutions and to analyze all relevant consequences of such solutions.

The university also undertakes contract work which is 100% financed by the contractor, but it only amounts to about 5% of the total research budget.

The government covers about 90% of the research expenses, and the rest is sponsored by private companies and international organisations.

This is the general frame in which the research activities take place, where new ideas are developed and where ideas in some cases are brought forward to a stage from which they can be transferred to commercial application by a private company. Existing companies have their own product policy, and they are often rather conservative and cautious. They are inclined not to take commercial risks outside their traditional business, and if they do it is often with a strong involvement by people from the university. Usually the new production is organised as a separate profit center or company.

In this general picture of technology transfer the small science based companies formed by spin-off from the university play an
important role. They represent a quick and efficient way of bringing research results to commercial use, and thereby contribute to the economy and to further developments of new business activity.

2. MOTIVES FOR ENTREPRENEURSHIP

The successful start of a spin-off company depends on many factors of which the personal factor is the basic one. Only people with a strong drive, selfconfidence and professional skill have any chance to manage such an operation and will be able to stay in business and even grow through the years.

Interviews with a number of entrepreneurs show quite clearly that the personal attitude towards starting a new technical company varies from a strong desire to be free and independent to more neutral attitudes where external factors such as 'an opportunity suddenly turned up' and 'there were no acceptable alternatives' formed the decisive motive.

In other words, we have 'pull' by personal ambitions as well as 'push' by outer circumstances as driving forces in this process.

Some of the entrepreneurs decided to make their own company and actually did it as a legal act before they even had an idea about what kind of products or service their company was going to offer. They looked for ideas during their study, and they tried to engage themselves in current research projects which they found interesting and promising from an application point of view. They got an opportunity to participate actively through final student projects, other project-organised courses or as assistants in contract work.

Several of them developed their ideas during a Ph.D.-study. For another group of entrepreneurs the idea of starting a science based business came gradually. They had a permanent position as teacher and researcher, and their scientific work and know-how turned out to have some interesting applications which opened up business opportunities.

Being in a permanent job with the right to do free research they were in a good position to prepare themselves for the transition to private enterprise, and in some cases they kept for some time a part-time job at the university after they started on their own.

About one third of the scientific personnel at DTH is not in permanent positions. They are working on short contracts or grants. Previously it was normal practice for graduates to work on contracts a couple of years while waiting for a permanent job, but in the seventies the scientific jobmarket became very tight. The economical stagnation simply did not leave any research positions open for young promising researchers. Therefore, they had to stay in contract work for longer periods, and they developed an expertise and a close contact with contracting companies, ministries and other customers for research and development work. After some time they felt that they could as well - or better - continue their consulting and
contract work on a private basis. They had already the product as well as the market. So, they started their own company.

3. STIMULATING ENVIRONMENTS

The present sympathetic attitude to entrepreneurship is a result of the slow economic growth and serious unemployment in the Western world. Commercial exploitation of research results has always been a subject of discussion and sometimes the cause of conflicts in the academical world. The problems concern: who gets the economical benefits and how can free research keep its independence?

A technical university must have a reasonable practice to balance these different interests in order to function as a creative working place for innovators and future entrepreneurs. Setting up a business ought to be seen as one of the career options of students and postgraduate students, and particularly by faculty staff, a true alternative to academic research.

At DTH the most productive faculties as concerns spin-off companies in recent years are the Electronics and the Civil Engineering faculties. Their research is highly relevant for business areas with growth such as energy conservation and conversion, telecommunication and data processing and various kinds of maintenance technologies and environmental protection. The expansion of these fields seem to open a number of opportunities for small companies with expertise. About half of the new firms started a production while the other half went into engineering consultancy. For example, the first experimental low energy house was built in 1975 by the Thermal Insulation Laboratory and the Institute of Building Designs. A young graduate was appointed as leader of the project and he has later started his own consulting company together with a colleague who specialized in heat pumps.

At one of the physics laboratories a research team was established at the time of 'the first energy crises' (1973) to investigate alternative scenarios for the supply and demand of energy in Denmark up to the year 2030. The research gave inspiration to the development of new energy saving products, and one student from this group started a company which has specialized in the design of very large heat pump systems for district heating. The world's largest heat pump was built in Denmark 1980.

Other spin-off companies started on basis of products which the founders and research colleagues had developed in concept or designed and built as prototype during their work at the technical university.

A group of teachers and Ph.D. students at the Department of Computer Science started a production of a small, versatile computer system and an automatic print lay-out system, both products which they developed at DTH. The company started in 1975 and has now grown to more than 50 people including 25 with an engineering degree.
Development of computer systems and software for special applications is the basis of several new companies. Also measuring and data processing systems for special purpose such as the evaluation of road pavement is now in production by new, small spin-off companies. Another new company is producing ultrasonic emulgators for oil-water mixtures. The idea came up during a final year project, and the development work was supported by the prototype workshop of the Inventors Office (a service office for inventors under the Ministry of Industry).

The Electromagnetics Institute has a long tradition in antenna design and has been able to form a real 'centre of excellence'. They do basic research and also contract research for international organisations such as The European Space Agency.

In 1973 a group of Ph.D.-students and a teacher started their own company for antenna research and design, and they are now doing consulting work for communication organisations and firms in many countries.

4. CONCLUSION

Entrepreneurship itself cannot be taught except for a few simple rules and procedures as regards setting up a business.

The important factors for the stimulation of spin-off activity are:

- An excellent research environment where students can be trained in scientific work and develop visions and ideas.
- An active effort to establish contacts with public and private organisations, industrial companies and other potential users of technological research.
- Contract research, which gives graduates an opportunity to obtain practical experience in project management.
- A general positive attitude to entrepreneurship in the faculty and the university administration.
- Active support to those who want to start a science based business. Such support may be loan of laboratory facilities and workshop and advice.
- A continued support and collaboration with the new companies, e.g. loan or exchange of personnel and equipment, student work, etc.

Even though the new science based companies seem to have a better chance to survive than many other small business companies it is still a risky affair to set up a technical firm.

The continued collaboration with a technical university may in some ways give a sounder base and thereby lower the risk.
INNOVATION AS A LOCAL PHENOMENON: CREATING AN INNOVATION INFRASTRUCTURE

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University of Sussex
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ABSTRACT

This paper presents data to show that technological innovation is often a markedly regional phenomenon. This is especially true of small firm innovations, largely because small firms are rather closely bound to local markets. Technology-based new small firms are suggested as a suitable vehicle for regional regeneration via innovation. The elements of a regional 'innovation infrastructure' favourable to the establishment of new technology-based small firms are then outlined.

INTRODUCTION

Today within most, if not all, the advanced market economies there
exist large regional differences in economic performance. The so-called development regions have for some years suffered relatively low rates of economic growth, relative industrial stagnation and relatively high levels of unemployment. Traditional regional policy—which has consisted mainly of cash grants, the provision of factory sites and regional training services, etc.—has, by and large, failed to redress regional economic imbalances.

The main effect of traditional regional policy initiatives has been to attract branch manufacturing plants to locate in the development regions and, when the recession came, these plants were the hardest hit, shedding jobs more rapidly than the parent companies. Evidence from the U.K. further suggests that, because of an inter-regional product cycle, the development of innovative products occurs largely in or near the parent plant while the branch plants receive more or less exclusively mature products to manufacture (Oakey, 1979). A third important problem is that of the imbalance between direct and indirect labour that often exists in branch plants; they generally contain few high level managers and technical specialists and a preponderance of unskilled assembly workers. This can have a negative influence on regional fertility since the propensity of local firms to spin-off new local firms is low for immigrant (branch plant) enterprises staffed mainly with unskilled workers (Johnson and Cathcart, 1980).

As a consequence of these factors, while the encouragement of branch plants of large companies to the regions has resulted in some short time relief of local unemployment, it has not resulted in long-term economic regeneration.

Because of the disappointing results of traditional regional development policies it is increasingly being mooted that longer-term regional economic development might better be achieved through the encouragement of small firms to establish in the regions. Certainly recent official government policy statements towards industrial and technological development in a number of countries have emphasised the belief that small firms are a favoured vehicle for economic regeneration generally (Rothwell and Zegveld, 1981). Small firms, it is claimed, are more than averagely innovative and are the most potent potential generators of new jobs.

There does, in fact, exist convincing evidence to suggest that in some areas of industry small firms are highly innovative, producing a much higher share in total sectoral innovations than their share in total sectoral R & D. There exists also evidence to suggest that small firms can generate new jobs at a faster rate than their larger counterparts. This, however, is true only of some small firms, notably young, technology-based and innovative small firms (Rothwell and Zegveld, 1982)
If, as is increasingly being suggested, the world economy is currently undergoing a period of structural change during which many new techno-economic possibilities are opening up which will in turn offer many opportunities to new technology-based firms, then the need to encourage the establishment of such firms in the regions is further heightened (Rothwell, 1981 (a) and (b)). In order to achieve this, however, it is necessary first to establish a suitable regional or local "innovation infrastructure".

The remainder of this paper will first describe briefly evidence which points to innovation as a 'local' phenomenon, and will then discuss the factors that together constitute a local innovation infrastructure.

INNOVATION AS A LOCAL PHENOMENON

Perhaps the most widely quoted examples of innovation as a local phenomenon are the developments in the 1950s and 1960s in Silicon Valley and on Route 128 in the United States. Here many new technology-based firms became established which played a crucial role in the evolution of the U.S. semiconductor industry. More recently a similar phenomenon appears to have occurred in the Boston area with the emergence of new small firms, linked to private venture capital companies and to university departments, in the field of biotechnology.

Turning now to individual innovations, Figure 1. shows the regional distribution in a sample of 300 important innovations introduced in the U.K. between 1965 and 1978 (Oakey, 1979). It can be seen that 34 per cent of all innovations were introduced in the South East region, while only 6.9 per cent were introduced in Scotland and only 8.2 per cent in the Yorkshire and Humberside region. Moreover, the South East region did especially well in the more technology-intensive industries, having 58 per cent of total instrument engineering innovations and 50 per cent of electrical engineering innovations. A more sophisticated analysis of these data, which took into account regional industrial structure and national innovation rate by sector, further emphasized the greater than average innovativeness of the South East region; the results of this analysis are shown in Figure 2. (Oakey et al, 1980).

This second analysis also showed that small establishments (less than 200 employees) were responsible for 60 per cent of all innovations credited to single-plant, independent enterprises, while only twenty per cent of multi-plant innovations were credited to the same plant size group. Further analysis revealed that while significantly more plants, both large and small, produced innovations in the South East than expected, in the Development Areas small firms performed precisely as the data average would suggest, but large firms performed rather poorly.
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A = Innovations

* Research & Development departments and non-British plants excluded.
Fig. 2. The effect of industrial structure on regional innovation performance (measured in terms of total manufacturing employment)

(a) Actual innovations
(b) Expected innovations (regional)
(c) Expected innovations (national)
(d) Residual (a-b)
(e) Expected variation in innovation due to industrial structure (b-c)

<table>
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<tr>
<th>Development areas</th>
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<th>57</th>
<th>-12</th>
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<td>72</td>
<td>17</td>
<td>9</td>
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<tr>
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<td>148</td>
<td>158</td>
<td>-5</td>
<td>-10</td>
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<tr>
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<td>287</td>
<td>287</td>
<td>287</td>
<td>0</td>
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</table>

Notes:
(a) The actual number of innovations recorded in each region with the actual regional industrial structure and the actual regional innovative performance.
(b) The expected number of innovations in each region given the regional industrial structure and the national innovative rate by sector.
(c) The expected level of innovations by region based on the region's share of GB manufacturing employment and the national level of employees per innovation.

N.B.: Figures rounded to nearest whole number.

Source: Oakey et al. (1980).

The above data might be taken to suggest that small plants are better suited to regional innovations - especially independent small plants - than are larger plants. This contention is supported by the fact that large companies tend to establish centralized R & D laboratories, thus localizing innovative effort often at the site of the parent establishment, which can make it difficult for branch plants to innovate in response to local market needs.

Another factor contributing to the local nature of small firm innovations is that the markets of small independent firms are often highly localized. This is illustrated for the U.K. in Figure 3.

Fig. 3. Sales in the Northern Region by new local firms and established plants

<table>
<thead>
<tr>
<th>Sales in Northern Region as a % of total sales</th>
<th>Number of new firms</th>
<th>Number of plants in 'Morley' sample*</th>
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<tr>
<td>0-5</td>
<td>7 (12%)</td>
<td>44 (53%)</td>
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<tr>
<td>6-25</td>
<td>8 (13%)</td>
<td>19 (23%)</td>
</tr>
<tr>
<td>26-75</td>
<td>15 (25%)</td>
<td>10 (12%)</td>
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<tr>
<td>76-100</td>
<td>30 (50%)</td>
<td>10 (12%)</td>
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</table>


which compares sales in the Northern Region of the U.K., as a percentage of total sales, of sixty new local small firms and eighty-three plants belonging to well established firms. Clearly the new businesses have significantly stronger links with local markets than do the established (branch)plants.

Rothwell (1979), in a study of the factors affecting competitiveness in the European agricultural engineering industry, also found that many small firms relied more or less exclusively on local markets. This often resulted, in the longer term, in technological backwardness in these firms, who tended to sell mainly conventional, low technology items to local farmers who, in turn, bought more sophisticated equipment from national, and often international, suppliers. This effectively shielded the local suppliers from technological developments occurring elsewhere.

To summarize, then, we can say that innovation, and especially small firm innovation, does appear to be a markedly regional phenomenon. A major contributing factor towards the regionalization of small firm innovations appears to be the heavy reliance of these firms on local markets.

CREATING A LOCAL INNOVATION INFRASTRUCTURE

A clue to the relatively high innovativeness of the South East region of the UK described above might be found in the fact that the South East region is more than averagely well endowed with research and development establishments. Thus, about 45% of private company R &D establishments are in the South East; 77% of other private R & D establishments are in the South East; 43% of Research Associations are in the South East; 54% of government R & D establishments are in the South East; 27% of universities and polytechnics are in the South East. Certainly according to the 1971 Census data, the South East region has an above average proportion of professionally qualified scientists and engineers.

Access to sources of scientific and technological know-how is, of course, only one factor in the technological innovation process, albeit an important one. It is, however, likely to be especially significant in the case of small firms which generally lack comprehensive in-house R & D capabilities, ready access to which might be an extremely important factor in their decision to locate in a particular area. The question of the spin-off of technically qualified personnel from R & D establishments might also be a factor, although there exists scant evidence of this phenomenon in the U.K.

Most studies of the innovation process emphasize demand-pull, or at least forward linkages to the market place, as a crucial factor in innovations (Rothwell, 1977) and, as suggested above, small firms
appear to be very much linked with local markets. This raises the question of the character of local markets and their influence on small firm innovations. Clearly in those regions characterized by a high proportion of traditional and low-technology industries, we would expect a high proportion of small firm innovations to go to firms in these industries. In the South East, in contrast, where there appear to be more firms operating in the modern industries, we would expect small firms to enjoy more innovative markets. Similarly, government laboratories, R.A.s, Universities and Polytechnics, and the R & D laboratories of large private companies, represent important markets for advanced scientific equipment, an area in which small firms continue to play an important role.

Thus, an important factor in the incidence of the establishment of small technology-based firms is likely to be the presence of innovative demand-pull in local markets. In the development regions it might be that innovation-oriented procurement on the part of publically owned organisations (e.g. hospital, schools, local authorities, universities and polytechnics) could go some way towards establishing increased innovative market demand (Rothwell and Zegveld, 1981).

Another, and rather crucial, factor in the start-up of new technology-based firms is the availability of risk, or venture, capital. Certainly when, because of government regulations, the flow of venture capital in the U.S. significantly diminished during the mid 1970s, the number of new public right issues on the U.S. stock market declined significantly (Morse, 1976). When the regulations were changed, the flow of venture capital picked up again extremely rapidly. Also, a significant reason for the Route 128 phenomenon around Boston in the U.S. was the willingness of local banks to finance new ventures. This contrasted markedly with Philadelphia where the banks were largely unreceptive. Of further relevance here is the situation in the U.K. where banks have not generally shown any willingness on a significant scale to fund new, innovative start-ups. Indeed, it is interesting in this respect to note that a new British subsidiary of Texas Instruments had acted as a financier to ten small microelectronics firms that were unable to attract capital from their local banks (Economist, July 5 1980).

There are, of course many other factors that might have a significant influence on both the rate and location of new technology-based start-ups, and a number of the more important of these are listed in Figure 4. In general we can classify all influencing factors under three main headings: supply (technology, skilled manpower, finance); demand (size and sophistication of local markets); and environmental (local regulations, local taxation policy, housing policy etc).

Any system of support at the local (and national) level for innovation in small firms and for the stimulation of new technology-based start-ups, must take into account the factors in all three of the above categories. There is, for example, little sense in establishing
Fig. 4. Some factors of potential influence on new firm start-ups

National and local regulatory climate including, at the national level, taxation policy.

Willingness of large private companies to provide financial and/or technical and/or managerial expertise to would-be entrepreneurs (e.g. Pilkington Bros. and the St. Helens Trust).

Access to government counselling services.

Access to government R & D funding.

Presence of local innovation-oriented initiatives, (e.g. the Tyne and Wear Innovation Centre in the U.K.; university based science parks, etc.)

Existence of a green field site.

Availability of premises.

Proximity to a new town development.

Availability of regional development grants.

Presence of special local authority initiatives.

Existence of technology-based large firms acting as an innovation demanding market.

Characteristics of the local labour market.

Quality of the regional communications network (railways, roads, access to airports and seaports).

a local source of technology supply if venture capital is unobtainable, the necessary skills are available and there is an unreceptive market. Finally, local culture is also of obvious importance and, while governments and local authorities might not, at least in the short-term, be able to significantly change the local culture, they can at least establish the conditions necessary for initiating cultural change and for enticing entrepreneurial individuals into the region.

REFERENCES


161
A UNIQUE DUTCH SOCIAL INNOVATION: THE SCIENCE SHOP

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Science Shop, Delft University of Technology
The Netherlands

ABSTRACT

The basis of the present Science Shops was laid by the student protests of the late 1960's. During the 1970's some twenty Science Shops were founded by progressive students and university staff members at practically every university. These Science Shops provide free advice to groups in society, which traditionally have had no access to scientific research facilities. The goal of providing such advice is to better the social position of these groups, which are considered to be "under-privileged". Now that Science Shops have functioned for several years it is apparent that they help answer an important social need.

RESUME

La base des Boutiques de Science actuelles se trouve dans la protestation des étudiants au fin du 1960's. Pendant les 1970's à peu près vingt des Boutiques de science sont fondé par étudiants et personnel universitaire gauchers à presque tous les universités. Ces Boutiques de Science pourvoient conseil gratuit à groupes en société, qui traditionnellement n'ont pas eu jamais accès au facilité du recherche scientifique. Le but du pouvoir ce conseil est amélioré la position sociale de ces groupes, qui sont considéré comme "pauvre en fortune". Aujourd'hui, que les Boutiques de Science fonctionnent pour quelques ans, c'est claire qu'elles aident satisfaire un besoin social important.

ZUSAMMENFASSUNG

Die Grundlage der heutige Wissenschaftladen befindet sich im studennten Protest am Ende der sechziger Jahren. In siebziger Jahren sind ungefähr zwanzig Wissenschaftladen von linken Studenten und universitäts Personal am fast jeder Universität gegründet geworden. Diese La-

*The author gratefully acknowledges the help of his colleagues at the Science Shop and dr.ir. S.M. Lemkowitz of the Department of Chemical Engineering for assisting in preparing the text of this article.

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1. INTRODUCTION

During the last ten years about twenty Science Shops were founded in the Netherlands, in particular at the universities. These Science Shops function as intermediates between what are known as "under-privileged groups" in Dutch society and research institutes, like universities. The aim of Science Shops is to obtain advice for these groups with which they can protect their interests in society. Advice is given gratis. The establishment of an institute for the benefit of groups, which traditionally have had no access to the scientific research community is an interesting social innovation.

2. HISTORICAL BACKGROUND OF SCIENCE SHOPS

a. Prelude

In 1908 an office called the "Social-Technical Advice Office" (STAO) was created in the Netherlands by an engineering society founded on social-democratic principles, the "Social-Technical Society of Democratic Engineers and Architects". The aim of this organisation was to advise, in particular, local governments, in social-technical matters, such as housing policy for workers' dwellings and public hygiene, for example waste disposal, drinking water supply and dust-control of unpaved streets.

Some general criteria existed for deciding whether a given request could be honoured or not. For example, the advice had to serve to raise the public welfare and/or to stimulate the democratic quality of society. The advice was given without cost. This office functioned from 1908 to 1914 and may be seen as the first Science Shop in the Netherlands; (Lintsen, 1980).

b. The student movement in the sixties

The STAO, however, is not the root of the present Science Shops in the Netherlands. From 1914, when this office expired silently, to the beginning of the seventies, no office of this kind existed in the Netherlands. The roots of the present Science Shops do not extend further than to the end of the sixties. At that time a large group of progressive students and staff members at the universities began to

*The highly motivating character of this "progressive" social-political outlook should not be underestimated, as it played, and still
protest strongly against the prevailing state of affairs. Reasons for this protest include: (Regtien, 1970)
- the growing realisation among students, that after their study they would simply be recruited by industry or government to manage man and machine, that is, to become part and parcel of the "establishment",
- the critical attitude of students about the widespread use of scientific and technological knowhow by the United States armed forces in the highly unpopular Vietnam war,
- the criticism by a significant number of academic personnel about university management, in particular because professors monopolized power at this time.

The demands of the protesting groups were democratization of the universities and participation in planning and managing education and research. They aspired to a decentralized university, structured in projects, in which students and staff members themselves democratically determine the research subjects and educational programs. As a result of this protest a democratization of university management was achieved in 1970. Additionally, new educational activities, Science, Technology and Society (STS) courses, were initiated at the faculties of natural science in the early and middle seventies. These courses aimed mainly at stimulating critical reflection into the effects of science and technology on society and the responsibility of scientists and engineers for these effects. STS courses were often quite philosophical in approach; (Slaa, 1979). Beside these new education activities rather nothing really changed in the education and research of the faculties of natural science.

c. Chemistry Shop at the University of Utrecht

An initiative that was particularly important for the present Science Shops was the founding of the "Workgroup Project Education" (WPE) in Utrecht by a group of left wing students and staff members. This group was permitted to introduce two experimental projects at the Department of Chemistry. The WPE began an investigation into local environmental pollution and secondly possible desinfectants for the Vietcong in 1972. By the end of 1973 however, the motivation of the group, which was strongly political, decreased because of the rather fundamental scientific nature of the environmental research and because results from the other project never reached Vietnam. Therefore the members of WPE decided to do research only in close relation with groups in society which, firstly, had no possibilities for carrying out research elsewhere and, secondly, could use the results of plays, the key role in establishing Science Shops. What progressive is is difficult to define clearly, but it contains elements of democratic-socialism, decentralization of power, anti "big business", pacifism, environmental protection, and is not without a somewhat utopian outlook.
research in their battle for a more socialistic society. With this
change in policy in 1973, the idea of Science Shops - in this case a
Chemistry Shop - was (re)found. Beside doing research, the members of
this Shop also took part in the actions of groups which they advised;
(Govers et al, 1975).

d. Institutes for Socially Oriented Research (ISOR)

A second development in the beginning of the seventies which led
to the foundation of the present Science Shops was initiated by a so­
cial-democratic society, just as had occurred in 1908. Following an
experiment which started in 1972 two collaborating Dutch societies of
scientists founded the "Advisery Bureau Safety and Health" in 1974 for
advising trade unions. After the need of this kind of advising had
clearly been established, these two societies formulated a proposal
in 1976 for the foundation of independent research offices, in which
scientists, employed by the government, could do research for groups
without direct access to the scientific community. Examples of such
"under-privileged" groups were trade unions, environmental-, adver­
sary- and citizen-groups. A year later, under pressure from, in par­
ticular students, this proposal was changed. The students argued that
completely independent research organisations could not alter prevai­
ling university research, and just such a change was considered abso­
lutely essential in realizing progressive aims. The resulting propo­
sal advocated the creation of intermediary units between under-privi­
leged groups and scientific research institutes like universities,
which would perform the actual research deemed necessary; (BWA/VWO,
1977). The "Advisery Bureau Safety and Health" and some other bureaus
of this type became "Institutes for Socially Oriented Research". Up
to now these Institutes have been run by volunteers, but there is a
good hope that in the near future the staff will be payed by the go­
vernment.

e. Criticism of Science, Technology and Society (STS) education

A third important stimulus for the foundation of the present
Science Shops is based on criticism of Science, Technology and Soci­
ety education at the Dutch universities. As already explained, this
education was rather of a descriptive and philosophical character,
and gave students no practical information about how to act in socie­
ty in accordance with their largely socialistic ideals. In 1976 a
conflict between academically oriented interests (STS-studies) and
activist-oriented groups reached a head; (Meertens et al, 1979). As a
result the latter groups decided to limit their activities to groups
in society which traditionally had never access to university research
facilities. These progressive students and staff members reasoned
that by cooperating with these under-privileged a socialistic ori­
entation could be given to university research. It was further argued
that under-privileged groups had the right of support by scientific
research because a large amount of scientific research was subser-
vient to other, powerfull centralized organisations, such as industry especially "big business", and government. These were the main arguments for the establishment of the Science Shop at the University of Amsterdam in 1977; (Wetenschapswinkel Amsterdam, 1978). The staff of this Shop were/is employed by this University.

f. Science Shop at Delft University of Technology

Most of the other Science Shops at Dutch universities were founded after 1977 in the wake of the formation of the Science Shop of Amsterdam. In 1979, after an initiative by progressive students and staff members, the Science Shop at Delft University of Technology was founded. In the beginning this Shop worked differently from other Shops, in that it also worked for small- and medium-size industries, as the University's Managing Board had required. At the end of the seventies, however, the central government initiated the foundation of Transfer Bureaus at the Dutch universities. After the foundation at Delft University of such a Bureau, which functions especially as an intermediary between this University and that kind of industries, the Delft Science Shop worked exclusively for underprivileged groups.

g. Need of Science Shops

In addition to the wish of progressive student and scientists to devote themselves to advising under-priviledged groups, other developments occurred in Dutch society which increased the need of this kind of advising. In the first place, at the end of the sixties and the beginning of the seventies many negative aspects of the rapid industrial growth of the fifties and sixties became highly visible, such as social alienation, caused by the rapid growth of huge, impersonal cities and organisations (education, government and industry), new risks for public health, caused by new large-scale processes in the chemical and nuclear industry, large-scale environmental pollution and a threatening lack of fossil energy resources and raw materials. These problems evoked strong responses from the public. Within a few years a number of impressive environmental-, adversary- and citizen-groups had formed which were greatly in need of scientific support. Secondly, at the beginning of the seventies the economic growth decreased dramatically. Demands of trade unions for higher wages and safer and better work were no longer automatically honoured. Also, at that time, industries themselves became more democratically managed and trade unions had more possibilities for making alternatives for policy. For these two reasons the trade unions were in greater need of scientific research than previously; (Meertens et al, 1979).

* It should also be noted that the increasing use of scientific knowledge in influencing decision-making was part of a process, more and more manifest since the Word War II.
3. HOW DO SCIENCE SHOPS WORK

a. The aim of Science Shops

Science Shops strive to obtain advice for under-privileged groups in Dutch society. Most of the Shops divide this aim into a short term and a long term one. The short term means direct help in answering requests from these groups. If it is a simple request, about which a Science Shop has ready information, the advice is given by the Science Shop itself. If it is a request about which specialized knowledge or research is necessary, Science Shops look for specialists or students. An Institute for Socially Oriented Research has in such a case more choice than a Science Shop at a university. An ISOR can choose between government research institutes and universities; a Science Shop at a university has only its university, but has the advantage that the distance between the Shop and specialists or students is shorter. The long term aim is more concerned with research in general since it is desired, as was previously mentioned in 2.e., that research change or at least be modified, so as to be more applicable to the needs of under-privileged groups.

b. Criteria of Science Shops

Not every organisation in Dutch society has access to the Science Shops. Only "under-privileged" groups are welcome. In this context under-privileged means "to have considerably less access to and to be considerably less able to use scientific and technological expertise than others (other groups)". In practise it means (Fortuin et al, 1982):

- a lack of knowledge about how to find and how to use relevant scientific and technological information,
- a lack of money to buy relatively expensive scientific expertise and research.

Beside these criteria relating to the requesting groups, Science Shops do not accept requests, when they are based on economical motives and when it is clear that a group cannot improve its position in society with a given advice. This last criterium is a rather difficult one, because it becomes clear whether a group can improve its position only after an advice has been given.

Science Shops do not have criteria relating to specialists or students who give advice. There are, however, some rules relating to the usefulness of information. Firstly an advice must be written in understandable Dutch or it must be clearly explained. Secondly, when a specialist or students do research for a group, this research must be primarily relevant to this group, and not, for example, primarily written for the scientific community. Thirdly, an advice must be given in time, because many requesting groups are involved in matters in which haste is important, like influencing decisions, for example through discussion or via law suits.
c. The intermediary function of Science Shops

For many requests Science Shops look for specialists or students who are willing to give gratis advice. After the acceptance of a request and when such specialists or students are found a number of procedures is possible. The easiest procedure is only to bring the requesting group in contact with specialists or students. In practice however, this procedure usually does not function well. This failure is due to the deep gap in knowledge and experience between these two parties. As a second procedure communication can be greatly improved by participation of the Science Shop in the consultation between the two parties. In a third procedure the communication between the requesting group and the specialists or students is divided into two parts. In the first part, in a consultation between the requesting group and the Science Shop, the degree of information and the most useful form of advice are determined. In the second part, the consultation between the Science Shop and specialists or students, the gathering of information or the necessary research is arranged.

d. Examples of requests

During the three years that the Delft Science Shop has functioned nearly 300 requests were received. About 10% were not honoured because they did not meet the criteria mentioned above. Many requests were related to living conditions. Thus the Delft Science Shop has received many questions about dangerous materials and transport through cities, local environmental pollution by chemical industries, illegal dumping of chemical wastes near housing projects, traffic noise, renovation of dilapidated houses, possibilities of lowering the energy use in houses, etc. Two of such requests will be explained below. The Shop have used different procedures for these two examples as was explained in 3.c.

i. Liquefied Petroleum Gas (LPG) in cities. Storage tanks of LPG can be found regularly at petrol stations in cities. Especially after an LPG-explosion in Spain in 1978, in which more than 300 people died or were severely injured, many citizens living close to such storage tanks started to press local governments to remove them. To support their demands a number of citizen-groups asked the Science Shop for information about the risks of these tanks. The Science Shop found a scientist at the Department of Chemical Engineering willing to gather information about these risks. A report was prepared describing these risks. In his report the scientist explained that these storage tanks were originally built without sufficient knowledge about possible accidents, explosions in particular. In that report it was also argued that drivers who use LPG, cannot have serious objection to tanking only at LPG-stations outside of cities; (de Rijk, 1980). After offering this report to the local governments all these governments agreed with the demands of the citizens. However, because of a lack of legal regulations these governments did not have the judicial powers to honour
the demands. The local governments thus shrugged off their responsibility by arguing that the problem of LPG-storage tanks was/is not a local but a national problem. Only in one case did the owner of such a tank remove it under pressure of citizens, brandishing the report.

ii. Ground pollution by chemical wastes. During the last two years a tremendous number of illegal dumping areas of chemical wastes were found in the Netherlands. More than ten citizen-groups, who lived in the neighbourhood of such dumping areas asked the Science Shop for advice about the character and scale of the pollution. They asked for support because they did not trust the analytical research initiated by the local governments. This lack of trust was caused by the — in many cases — complicity of the local governments for the dumping of chemical wastes. Initially the Science Shop itself judged critically the analytic research which was already done. When questional results or procedures were found the Science Shop had supplementary research carried out at the Analytical Section of the Department of Chemical Engineering. These critical judgments and the supplementary research results were used as counter-expertise by the citizen-groups to the local governments. In this way citizen-groups could better defend their interests with regard to their problems about ground pollution.

4. FUTURE OF SCIENCE SHOPS

The several years that the Science Shops have functioned, have clearly demonstrated that the Science Shops help answer a great social need. However, Shops have been functioning for too short a time to make a good evaluation about the social impact of the advice so far given. The future will show whether Science Shops can significantly improve the social position of under-privileged groups. Much will depend on the policy of, in particular the universities, because most of the Science Shops exist at universities and are thus dependent on the number of "shop personel" employed and the amount of time which staff members and students are allowed to spend in gathering information and/or performing research for requests accepted by the Science Shops.

REFERENCES

Theme 3. Continuing Education

a. Engineering education and technological change
b. Adapting higher education institutions to continuing education
c. Integrating job and education
d. Barriers and incentives to continuing education
e. Improving innovative performance

Chairmen: W.B. Palmer (Great Britain) and N. Krebs Ovesen (Denmark)
Rapporteurs: J. Eekels and H.H. van den Kroonenberg (the Netherlands)
CONTINUING EDUCATION

J. Eekels
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The Netherlands

In this world of rapid technological change one is aware of the fact that the scientific and technological knowledge with which a university graduate enters his engineering career is subject also to a process of fast obsolescence. Around 1950 it was considered that an engineering graduate loses 50% of his scientific value within 10 years. Nowadays there are rumors that this period has reduced to 5 years. If this rate of obsolescence continues, then an engineer would practically be worthless within 15 years after leaving university. Fortunately, this process is partly set off by his gaining practical experience. Partly, not completely. In general his career develops within a rather restricted area of engineering and industry, and there is a real danger that he is insufficiently aware of what happens in adjoining regions, although he may develop into a first class specialist in his own discipline. And then suddenly his own discipline may be overrun by technology from other regions and he may be at a loss. Apart from this he will rise in the societal hierarchy, but this will entail an ever broadening responsibility necessitating decisions concerning issues far away from his original specialism. In former times experience could make up for these phenomena. Today this is no longer true and the gap gradually developing has to be closed by more or less formal educational measures that are comprised under the concept of continuous education. This is well known and I hardly need to tell you about this. SEFI is for many years aware of this too and a hard working Working Group under the chairmanship of Prof. Krebs-Ovesen is doing excellent work in this respect. As to the subject of continuing education in general I only have to refer to the proceedings of said Working Group and especially to the recently published book on Continuing Education by Prof. Krebs-Ovesen.

As I mentioned before, there are two main reasons for continuing education, viz. rapid obsolescence of the body of technological knowhow for a certain discipline, which requires updating that body of knowledge on one hand and a need for knowledge of a more encompassing nature relevant for widened responsibility on the other hand. It is the latter aspect that caused our Working Group Innovation to establish a subgroup for continuing education too. Far from being a competitor to the Working Group Continuing Education, our subgroup on continuing education intends to devote its attention specially to continuing education related to innovation and entre-
 entrepreneur. An engineer called upon to be an innovator or wanting to become an entrepreneur is in need of a number of capabilities university has not taught him. Certainly, we are convinced that incorporation of at least part of these items into the normal curriculum is a strong necessity, and parallel session 1 gives many valuable contributions in that direction. Yet it is a matter of fact that for most engineers that have graduated in the past, and for many still to graduate in the near future, there is and will be a painful gap in their knowhow as to this, and continuing education has a definite task to fulfill in this respect.

There is more. The subgroup realizes that there is not only a need for continuing education for graduated engineers that have entered an industrial career, but also for engineers that entered an academic career and joined the staff of some university. I must confess that the subgroup, established only a few months ago, has only made a feeble start of its work. Its main action is programmed for after this conference and it intends to integrate the results of this conference into its own work.

I feel very happy, therefore, that such an outstanding group of scientists both from academia and industry, have contributed to the theme of this parallel session. What are we going to hear? Let me try to give you a bird's eye's view of the programme:

- Mr. Ascione from Italy will show us how a huge telecommunication corporation established its own post-graduate and continuing education school. A remarkable feature is that the innovation aspects are taught in cooperation with the Polytechnic of Design.
- Mr. Brohn emphasizes the development of intuitive skills in mechanical engineering.
- Mr. Brown warns us that course topics must be continually updated.
- Mr. Eekels will report on a recently established post-academic course on innovation management at the Delft University of Technology.
- Highly interesting is the contribution of Mr. Lehto from Finland, who demonstrates a programme in which simultaneously unemployment under engineers is reduced and new industrial enterprises are established.
- Mr. Popovic demonstrates that also industrially developing countries are in need of continuing education, but that the special prevailing circumstances require specially designed schemes.
- Mr. von Queiss shows that continuing education is not a modern fashion only: the need for it existed already 80 years ago.
- Mr. Thust represents the industrial view. He clearly demonstrates that there exists a gap between what university offers and what industry requires. This gap (which I am inclined to call the educational gap) has to be closed by continuing education. He also stresses the point that there can be a strong and important feed-back from continuing education to the formal university curricula.
Mr. Wearne finally approaches the problem of continuing education from the other side: a multitude of post-academic courses are offered and it is very difficult to find one's way in this collection. As a genuine scientist he speaks of the entropy of continuing education and he reports on actions taken in Great Britain for lowering this entropy.

I am confident that this important topic will be discussed in detail during the parallel sessions.
ENTREPRENEURIAL AND INNOVATIVE ASPECTS OF ENGINEERS' TRAINING IN AN ITALIAN POST-GRADUATE SCHOOL

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ABSTRACT

The STET Group (responsible in Italy for tlc. and electronics) numbers some 130,000 employees; it has established (1972) its own post-graduate school.

Programs for managers include special training for developing their managerial skills, while the innovative aspects are covered in appropriate courses; contacts have also been established between one of the manufacturing companies and the Polytechnic of Design, in Milan.

RESUME

Le Groupe STET (actif en Italie dans les domaines des tlc. et de l'électronique) comprends quelques 130,000 employés; il a fondé (1972) son école supérieure, à L'Aquila.

Les programmes pour managers comprennent une formation spéciale pour développer leurs capacités spécifiques, tandis que les aspects innovatifs font l'objet de courses ad hoc; des contacts ont aussi été établis entre l'une des sociétés de fabrication et le 'Polytechnic of Design', siégeant à Milan.

ZUSAMMENFASSUNG


Diese Gruppe, die jetzt mehr als 130,000 Beschäftigte hat, darunter mehrere Tausend graduierter Ingenieure, hat 1972 eine eigene Weiterbildungs-Internatschule gegründet, die sich nicht weit von Rom befindet. Sowohl für junge als auch für erfahrene Ingenieure werden verschiedene Seminare und Programme angeboten, die sowohl die Grundausbildung als auch die Weiterbildung umfassen.

Programme für junge Manager schliessen ein besonderes Training ein - manchmal auf internationaler Basis, um ihre Management - Fähigkeiten weiter zu entwickeln, während die innovativen Aspekte,

1. INTRODUCTION

The STET Group established in 1972 the 'Scuola Superiore G. Reiss Romoli', with the purpose of giving graduated engineers of its companies the technical information they require; the School runs also special programs for updating the technical background of its managerial staff.

STET is the holding of a group including several telecommunication companies (such as: SIP, ITALCABLE and TELESPAZIO), as well as a number of manufacturing companies, e.g.: ITALTEL, SELENIA and SGS/ATES. STET was established back in 1933, as the first Sectorial Holding within the framework of I.R.I. (Industrial Reconstruction Institute).

Its activity was, at the beginning, confined to the field of service companies; after W.W.II, it gradually acquired several interests, both in the fabrication and in the installation plus ancillary activities. At the present time, the dimensions of the Group are rather large, at least according to European standards: all told it numbers more than 130,000 people, with several thousands of graduated engineers.

By the turn of the seventies, the Group felt acutely the need for a post-graduate school of its own, when an opinion research was also run in all its companies, in order to ascertain the educative requirements for both initial formation of newly hired engineers, and continuous education of senior technical staff.

In April 1972 a trial activity was started in a temporary seat at L'Aquila, a pleasant mountain town not too far from Rome: several one-week seminars were scheduled for the requirements of continuing education, as identified above.

2. THE MANAGERIAL APPROACH

STET is well aware of the large wealth of human resources it has available: this leads to a consideration of urgency, as applied to the maintenance/enrichment of said patrimonium, through its most suitable use as well as continuous enrichment of the potentialities inherent to each manager. It is a long felt requirement, largely capable of shaping - in the better or in the worse - the future life and development of the whole sector.

It is therefore required to find and develop suitable systems and
procedures, capable of generating the smooth evolution of each individual, by making leverage upon the potentialities laying within him. An interesting approach has recently been that of organizing at L'Aquila a special 'Course for Research and Development Supervisors'.

Said course - lasting five and a half days - can be identified as an introduction to the typical 'managerial seminar' of American origin, fully adapted and modified to meet Italian requirements. Much emphasis is given to the main areas of: a) duties and responsibilities of the R & D supervisors, and b) improvement of oral communications with individual employees. Evidence of this is given by the heavy percentage (some 70%) of the total time which has been allotted to both group discussions and practice sessions (role playing).

Other subjects covered by the course, include: technical expertise of R & D management personnel, continuing education, evaluation of performance, planning, technological advancement and relationship between marketing strategy and R & D. No textbook was available nor given, but copies of all transparencies projected - some of which arose from group and class discussion - were supplied to every participant.

This course is only one among the various efforts now being applied by the Group in order to foster an innovative approach in its younger supervisors and low level managers. The integration already existing within the Group, implies an added requirement for innovation, while - at the same time - the now much heavier than before commitment in the world market, renders the 'innovative' demand a particularly heavy and stringent one.

In order to stress and underline this connotation, to be broadly considered as managerial plus entrepreneurial capabilities in the whole, the Group has lately started another program - for its executives - which follows a modern approach, splitting into two halves and into several 'modules' the whole span of its purport.

The School houses one half of the program, while the second takes place outside Italy, in order to compare the 'national' scenario with other, foreign and worldly experiences; a general survey of managerial training activities (as usually performed in Europe) has shown that the program should be made available to a little less than 100 people per annum. There will be five modules, of five days each, suitably intervalled, so that the whole program will typically require a period of some 14 months, as an average.

A close inter-relationship has been built into the modules of the course, so as to make up a unitary formative program, having the main aims of developing a global insight for these subject areas:

- corporate organization;
- external ambient;
- market dynamics;
- technological evolution.

Besides said areas, much care is usually given to the role played
by each executive in the company and for the same; he is seen as the keen administrator of human resources, as well as the person solely responsible of operative engagements and of corporate results.

This training activity fully exploits teaching and training methods of an active type, with much of the total time being allotted for the relevant options: therefore the bias is strongly bent towards the implication of each and every participant, so as to make him the real protagonist of his formative processes. As one can easily deduce from which has been said, the philosophy of formation leans fully upon a work of progressive updating within the framework of corporate structures, as well as of operative procedures. This is well kept in mind and the general results of the course have been consistently satisfactory.

3. THE INNOVATIVE ASPECTS

In recent years, in both the USA and Europe there has been a growing concern over the reduced level of technological innovation leading to useful products in the marketplace. Even the impact of research at universities in establishing new high technology industry, and in launching new products on the market, has proved to be rather small.

Among the many factors which contribute to this state of affairs, two are of particular significance to educators: a) the knowledge that university graduates have of the innovative process; and b) the attitudes that university graduates have toward individual or collective entrepreneurship.

As it has been said, the School at L'Aquila runs yearly also a course for newly hired engineers, starting their career in the manufacturing companies of the Group (SELENIA, ITALTAL, ELSAG, SGS/ATES, etc.). This course has succeeded in avoiding the usual pitfalls in which, and owing to which, most engineering curricula usually fail; in fact said curricula concentrate on scientific understanding, on analysis and on technical design. They usually ignore the many other facets of innovation, such as: costing, market analysis, production organization and financing.

Most students emerging from these curricula, see themselves as potential employees in established enterprises with a solely technical role. For those who dare to become entrepreneurs, the success rate is quite low, mainly because of lack of knowledge concerning important, non-technical aspects of the innovative process.

As it has been remarked (mostly by Yao and Jansson), there presently appears to exist in most universities a gap between the teaching in the schools of engineering and in those of management; in other words, the harmonious 'meeting of the minds', which requires an understanding of both technology and management, is not effectively covered by either institution. In fact, neither 'handbook engineering' nor 'engineering science' deals with technological in-
novation as a possible area for teaching. Innovation represents the mixture of various technologies in specific configurations, provided by innovators outside of the academic circle. The final objectives, as represented by product specifications, may be realized through optimization of the parameters of the relevant configurations.

Engineering education represents the teaching of the basic tools, in the firm of technology, and the methodology to accomplish the design optimization. This latter may vary from the exercise on the drafting table, to the modern day version of computer-aided design. In either case, a straightforward method can be mapped out after the specific configuration is known: it is in this format that technological innovation is generally ignored.

The course above referred to, means for engineers newly hired by fabrication companies, has the scope - among others - of giving its participants a basic, sound knowledge of innovative thinking and practice, sometimes enhanced by the intervention of famed designers who help in the solution of some projects. The general formula of this training activity, follows the typical 'sandwich' scheme, inasmuch that several 'sub-courses' are provided, to be mutually interlinked by work period in the parent company. This continuous feed-back of learning towards actual experience, and vice-versa, ensures a good efficiency in the learning process, and has been appreciated by the course participants.

4. THE POLYTECHNIC OF DESIGN IN MILAN

Through the casual occasion of a study visit, paid by the students of this school to the works of a STET's Associate (not far from Milan), some contacts have been taken with its Founder, the famed designer M.N. Di Salvatore. His institution works on an international basis, for the vocational training of designers, by providing all the means required and suitable for an advanced teaching at an academic level.

The Milanese School organizes and runs Design Courses (duration: two years), closely following the didactic techniques and teaching methods set out after a careful study; up to now, its certificates are of no legal value, since the School's Management seeks only to achieve - in complete freedom, even if under the supervision and approval of the Italian Ministry for Public Education - a high degree of professional/vocational qualification in the difficult and complex field of industrial design.

The value of the qualification offered and attained, will depend solely upon the capability of each former student to work in industry with a role 'consisting merely in the capacity to carry out other people's creative work', as is written in an official presentation of the school, signed by Mr. N. Di Salvatore himself. As it has been already pointed out, the School tries wisely to take as much advantage as possible of its location, in the very heart of academic and industrial Milan; so its students participate frequently to
visits paid to industries, design centres and industrial exhibitions, so fulfilling one of the wise rules set out by their own dean and principal.

5. CONCLUSIONS

With an increasing number of university-industry interactions, it is becoming more apparent that academic and industrial research and development ties are the wave of the future. However - as it has been pointed out - we are 'only scratching the surface', as far as quantitatively determining the role of Government in promoting this wave.

According to some sources, among which the Tomkins Report, Italy is not particularly strong in stock and deployment of Scientists and Engineers in R & D, so that any activity and effort purporting to improve our national outlook, is high priority matter. It is the role of applied research people to seek out and identify the most important technological needs and opportunities before they become critical, perhaps 5 to 10 years ahead. In this short description, it has been tried to give a reasonable account of the innovative and entrepreneurial aspects embodied within the training activities of the School at L'Aquila, keeping in mind the ever important relationship between university and industry.

REFERENCES

THE DEVELOPMENT OF INTUITIVE SKILLS IN STRUCTURAL ENGINEERING

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ABSTRACT

The results of a ten year study of the development of intuitive skills in Structural Engineering are reported. The investigation has focused on the development of testing procedures to evaluate the way in which undergraduates acquire an understanding of structural behaviour. The control group for the tests is the graduate intake into the firm of Ove Arup and Partners. The results show that many recently qualified graduates have a poor understanding of structural behaviour.

The later stages of the research project have been directed towards appropriate teaching methods to correct the apparent deficiency, with encouraging results.

RESUME

Le rapport fait ressortir les résultats d'une étude de 10 ans sur le développement des compétence intuitives dans le domaine de la construction structurale. L'enquête était concentré sur le développement des procédés d'essais de manière à évaluer de quelle façon les futures diplômés arrivent à comprendre la résistance des matériaux. Le groupe-témoin pour les essais comprend le nombre des diplômés admis dans l'entreprise Ove Arup and Partners. Les résultats montrent que beaucoup de jeunes diplômés récemment qualifiés éprouvent des difficultés à comprendre le comportement des matériaux.

Les derniers stades du project de recherche ont été dirigés vers des méthodes d'enseignement pertinentes afin de remédier aux lacunes évidentes, et les résultats sont encouragers.

ZUSAMMENFASSUNG

Die späteren Phasen des Forschungsprojektes richteten sich auf geeignete Lehrmethoden, um diese Schwäche zu beheben. Die Ergebnisse waren ermutigend.

1. BACKGROUND

Ten years ago I faced a class preparing for the final examination of the Institution of Structural Engineers. This examination is a daunting prospect, because structural design work, equivalent to about three months in a design office, must be summarized in less than seven hours. There is no time for detailed calculations. The candidate must rely upon his understanding of structural behaviour to create a safe, sound structural solution. At that time I equated 'an understanding of structural behaviour' with the ability to arrive at the qualitative solution to a structural problem.

I was surprised to find that many of my colleagues disagreed. The predominant view was that this understanding could be judged by the ability to solve numerically-based problems. Clearly, this was an issue of some importance and one which would benefit from investigation.

2. TESTING AN UNDERSTANDING OF STRUCTURAL BEHAVIOUR

I discussed this matter with senior staff of Ove Arup and Partners in London, and they agreed to my testing their graduate intake. Pilot tests were carried out in 1972 and 1973 with a 48 item test, Grad 1, consisting of two-dimensional line diagrams without load or dimension values. The candidate was required to draw the qualitative bending moment diagram. The mean score of around 40% was surprisingly low. A new 20 item test, Grad 2, on which the subsequent research was based, was produced from the pilot test. It should be noted that all the structures are well within the capacity of any Civil engineering graduate to analyse numerically.

The results of the tests conducted to date at Arups and with other groups are shown in Table 1.

Table 1

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<td>2 1973</td>
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<tr>
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<td>Arup</td>
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</table>

'HK'. Students on the Higher Diploma in Structural Engineering at Hong Kong Polytechnic.

Grad 4. Matched test to Grad 2.
Grad 5. Post-test similar to Grad 2.

An analysis of the results reveals that the test candidates fail to understand the relationship between the deflected shape, reactions, and bending moment diagram, and leave an incorrect solution without, apparently, testing its validity in any way. This is clear if we inspect one of the test items.

1. Grad 2. Item 20. This incorrect solution should have been recognised because the sagging moment in the beam BC would require a vertical reaction at D.

2. If the structure is released at D it is apparent that the horizontal reaction must be to the right to return point D to the original position.
3. The correct qualitative solution.

The explanation for the failure of the majority of the test candidates is quite straightforward. They have no strategies to solve problems of this type because none have been taught.

3. ENGINEERING PRIORITIES

When the results of the pilot and the first 20 item test were published (Brohn 1977a) and discussed at a Colloquium (Brohn 1977b), the audience, consisting predominantly of professional engineers, were unanimous in their view that the results revealed a deficiency which they had recognised independently, and that the type of skills covered by the test items were essential to the structural engineer.

It has become clear that this issue of 'understanding' is part of a much wider debate between groups of psychologists and philosophers, as to the meaning of 'intuition' and 'knowledge'.

Two viewpoints are clearly discernable. The Behaviourist school holds that knowledge and understanding are essentially explicable in terms of a stimulus-response mechanism (Watson, Skinner), and that this is implicit in the views of many lecturers in technological areas, particularly those responsible for subjects with a substantial mathematical content. The student will be seen to understand the particular theory if he is able to solve a problem numerically. The contrary view, held by philosophers like Popper (1959), Medawar (1969), and, most perspicacious of all, Feyerabend (1978), is that a model of understanding must be related more to the unique, intuitive wholistic response of the individual. Koestler (1967) puts the issue quite clearly;

'The citadel of orthodoxy which the sciences of life have built in the first half of our century rests on a number of impressive pillars, some of which are beginning to show cracks and reveal themselves as monumental superstitions....'

'...That the only scientific method worth the name is quantitative measurement; and consequently that complex phenomena, must be reduced to simple elements accessible to such treatment with-
out undue worry whether specific characteristics of a complex phenomena, for example, man, may be lost in the process.'

But these commentators are not discussing structural engineering. However, those engineers who have concerned themselves with the underlying philosophy, show the same concern for the excessive concentration on numerical methods in modern schools of Civil Engineering, the same lack of balance in the curriculum, which has allowed the student to graduate with such a poor understanding of structural behaviour. This from Nervi (1956) will be sufficient to show that this matter has always been of much concern;

'It is highly regrettable that some of the highest qualities of the human mind, such as intuition and direct apprehension, have been overwhelmed by abstract and impersonal mathematical formu-lae.'

4. TEACHING AN UNDERSTANDING OF STRUCTURAL BEHAVIOUR

The analysis of test results reveals that the incorrect qualitative solution for the bending moment diagram would be recognised as such, if the candidate could see the relationship between the deflected shape, reactions, bending moment and axial load diagram. That then presents a straightforward way of correcting this deficiency. In a recent evaluation of this approach, a group of graduates was tested with Grad 2, mean score 38%. After a period of instruction using specially prepared teaching material this group improved to a mean of 54%.

The effectiveness of this predominantly qualitative approach to the development of understanding has important implications for undergraduate study.

There is little doubt that structural engineers recognise the importance of intuition in obtaining sound solutions. This is taken from the Institution's 'Aim of Structural Design' (1975).

'As many facts and factors as possible are collected and assimilated; the mind concentrates upon them, immerses itself in them. By some process of the intellect or imagination, often in moments of relaxation, concepts of the general structure suggest themselves, sometimes vague, sometimes surprisingly complete.'

If that is to be a model for the thinking processes of the Structural Engineer, the predominantly mathematical approach to analysis and design will not be an adequate preparation.

What it requires is practice in wholistic problem-solving, and that is a description of the process used to solve the test items in Grad 2. There is no obvious entry point or route through the problem, the analyst must be able to 'see' the physical response of the structure and recognise the resulting effects. The solution
is essentially a 'best-fit' to the criteria of compatibility and equilibrium.

5. INNOVATION

I recently took part in an exercise with an International firm of Civil Engineering Contractors, which operates at the limits of modern design and technology in its work on undersea oil storage platforms, windmills and similar problems. This exercise was arranged for senior staff, in an attempt to free them from the scientific 'tramlines' which were failing to yield adequate solutions to radical problems. The qualitative solution of structural frames was used as an example of the way in which real engineering problems are rarely, if ever, a matter of the application of linear analysis, but a continual adjustment of solution to fit the criteria. The essential requirement is a language by which these matters can be discussed. In the solution of structural engineering problems that language is a coherent diagrammatic presentation of the response of the structure to load. This qualitative, intuitive approach is a more effective model of real design decisions compared with the predominant, mathematical approach to engineering, and is, as such, a vital tool in the solution of innovative problems.

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EDUCATION BEYOND FIRST DEGREE LEVEL

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ABSTRACT

In a progressing subject like Electronic Engineering, education is a process that should continue throughout a career. The need for continuing education is considered and the ways in which it can be met in a technological university discussed. Industrial involvement in the planning and execution of taught masters courses, short intensive courses and collaborative research projects is of immense benefit. Examples of such courses offered by the University of Surrey, together with a review of objectives and success, are given in the paper.

RESUME

Dans une discipline évolutive comme le génie électronique la formation doit être un processus continu, s'étendant sur toute une carrière. Nous considérons dans cette communication la nécessité d'une formation permanente et les moyens de répondre à cette exigence dans une université à vocation technologique. Nous mettons en lumière les avantages inestimables qu'apporte la collaboration de l'industrie à la conception et à la mise en œuvre de cycles d'études en vue de l'obtention d'une Maîtrise, de stages d'études intensifs et de projets de recherches menés en commun. Nous présentons des exemples de programmes de ce type proposés par l'Université du Surrey, en précisant les objectifs et le bilan de ces expériences.

ZUSAMMENFASSUNG

In einem sich entwickelnden Fach wie der elektronischen Technik, sollte die Ausbildung die gesamte Karriere erfassen. Die Notwendigkeit für fortlaufende Ausbildung wird behandelt, ebenso die verschiedenartigsten Möglichkeiten einer solchen fortlaufenden Ausbildung in einer technologischen Hochschule. Teilnahme an der Ausarbeitung der Pläne und praktischen Arbeit der programmatischen Magisterkurse, kurzfristige Intensivkurse und auf Zusammenarbeit beruhende Forschungsprojekte erweisen sich als äußerst vorteilhaft. Beispiele derartiger Kurse, welche die Universität Surrey anbietet, in Verbindung mit einer Besprechung der Ziele und dem erzielten Erfolg werden in
1. INTRODUCTION AND BACKGROUND

Any nation which relies on manufacturing for much of its wealth creation has a continuing need for better innovators. Great Britain is such a country, some 80% of its wealth comes from manufacturing industry, and engineering constitutes about 50% of this output. Of total exports, 80% are manufactured goods, about half of which is a direct result of engineering. Industry's competitiveness relies heavily on the innovative ability of its employees and it is imperative that skills are maintained throughout a working career. The dictionary definition of innovation - 'to make changes by introducing new ideas' - does not fully reflect the need of an engineer to know and understand his technology, to recognise industrial requirements and to use his knowledge, ability and ingenuity to achieve a result of technical and commercial merit. At a time of rapidly progressing technology and sociological change an engineer can no longer rely on information gained during his first degree to equip him for a career spanning several decades. Continuing education is increasing in importance, but its potential in a modern industrially-based society cannot be over-emphasized.

A basic education is essential for any profession, but engineering graduates of universities are still at a very early stage in their development and require experience before they can apply their innovative skills to the full. Links with educational establishments should not terminate at graduation. Indeed, with a person's increasing maturity and experience, further relevant and applicable courses will accelerate development. Improvements can also be made in the innovation potential of industry by increasing the effectiveness of the existing stock of practising engineers since many will have scant knowledge of important topics which did not feature at all in undergraduate courses as little as three to five years ago! If a degree course has been successful, graduates should have a sound knowledge of the underlying principles of their subject together with an awareness of current practice. They should have acquired a critical approach to scientific and engineering problems and be aware of solving techniques, have learned to use resources at their disposal and developed individuality and a degree of ingenuity. They are in a position to take a responsible role in industry but the learning process continues throughout a career. The first degree is a valuable platform from which the graduate can leap in many directions. It must have provided the coverage of fundamental scientific principles and basic engineering practice necessary for a specialist career at first, but also enable a redirection of career at a later stage if desired.

Any post-graduation course will need to be more specific than the first degree - more related to the engineer's requirements at that stage of his career. Course organisers must consider such needs very
critically before developing curricula which try to meet industrial requirements and develop innovative skills. The difficulty of the task must not be underestimated, because requirements vary enormously and it is likely that several different types of course on many different topics must be offered. It is unusual for any one educational establishment to have either the expertise or resources to mount but a few, so some national scheme that could co-ordinate this activity and avoid excessive duplication would be of immense value.

The Finniston Report on the Engineering Profession, published in 1980, made some significant proposals regarding continuing education, including the establishment of Regional Centres to oversee and encourage its development. However, until such a proposal is adopted, individual universities and colleges must take the initiative in assessing the national need and attempt to provide suitable courses.

2. REQUIREMENTS OF CONTINUING EDUCATION

The most immediately obvious requirement is for specialist engineers to keep pace with the latest developments in his own, often narrow, area of interest. This is probably the most difficult need for a university to fulfil unless it has a research team working in the field or one very closely related. Published literature is just as available to the industrial or professional engineer as to the academic don so it is unlikely that a course in the subject will advance the engineer's knowledge. Further understanding of latest developments and recognition of their implications is best achieved by industry-university research collaboration. The stimulus could be increased if such a liaison were to lead to a Masters or Doctorate degree as described in section 6.

Of great relevance to a large number of engineers is the gaining of an awareness of how an associated topic, closely related to his own, has progressed. This has been especially evident in Electronic Engineering of late since most engineers have needed to become aware of developments in microprocessor technology and applications and in microelectronics. Oftener after serious study, these new techniques can be used to advantage, so that the acquisition of this further knowledge will have enhanced problem solving skills. Individual engineers may also need to advance their knowledge in certain fields in order to change their area of activity within a company, or on joining a new company, or to simply prepare themselves for the future. The most appropriate form of continuing education here would be via a series of short intensive courses, or by a taught Masters course. Such courses must contain an element of experimental or design work as this allows the learner to gain first hand experience of difficulties, recognise the applications and enjoy the stimulus of successful practice.

Despite the often stated reluctance of engineers to become involved with management and economics, most will eventually become project leaders and some will aspire to be technical managers and
directors. Although a significant amount of knowledge, for example, marketing, business, product planning, organization and finance, will be gleaned through experience with a company, it is probably best put into context through university courses. Of late, many more undergraduate courses are introducing an element of business management, but it is debatable whether undergraduates in their teens or early twenties have the maturity or appreciation of industry to benefit fully from such courses. The opportunity for further study must be offered at a later date, the ideal probably being some 10-20 years into an engineer's career. Courses in technical and project management should remain within the scope of engineering faculties where management of engineering is stressed rather than general management theory. Again short intensive courses or taught masters courses will cover the requirements.

Sometimes, due to an engineer's changing interests, or more drastically, because of the decline of a company or a discipline, a career redirection is necessary with the accompanying need to convert from one engineering discipline to another. Also, graduates from pure science or even a non-scientific subject may wish to retrain in a branch of engineering. If the person concerned has some knowledge of the basic requirements of the subject such a conversion may be achieved via a taught M.Sc. course, otherwise it may be necessary to study all or part of a B.Sc.

3. INDUSTRIAL INVOLVEMENT

There is no doubt that industrial companies are, to a greater extent than ever before, recognising the value of liaison with universities to improve the innovative skills of their workforce. This undoubtedly reflects the increase in the number of trained engineers who are involved with planning and project organization. Engineering graduates are being used in all parts of the industrial process and not simply in research and development, and continuing education should be used to make engineers aware of more aspects of manufacturing. Much of this can be done in-house but industry's assistance in evaluating its needs, realistically assessing where knowledge up-dating is required and anticipating future trends, can be of tremendous value to course organizers.

Universities must be able to convince industry that the release of employees, who are often working to very tight schedules and deadlines, has a long term advantage in bringing new ideas and methods to the companies. It is difficult to visualise continuing education ever being a right of the individual; indeed, such a system is not desirable since efficient education requires the willing involvement of all concerned and an imposed commitment would, in many cases, be counter-productive. All courses must be run in a highly professional manner to deserve support and be conducted at a reasonable cost. Universities must always provide the best available expertise and invite selected industrial contributors to strengthen weak areas.
Only with university-industry interaction will courses be offered which maintain the technical expertise of engineers at a level which maintain the technical expertise of engineers at a level which is of maximum benefit to industry and the nation.

4. TAUGHT MASTERS COURSES

The Engineering Faculty of the University of Surrey runs several full and part-time M.Sc. courses. One of these, the Systems Engineering/Microelectronics course of the Electronic & Electrical Engineering Department, is briefly described here. The course originally covered two major subjects, Computer Engineering and Automatic Control and was conducted on a 12 month full-time basis. In the mid-1970's it became evident that industrial companies were becoming reluctant to release and sponsor employees for such a long period of time. The U.K. Government at that time reduced the number of grants available for M.Sc. courses. It was obvious that students would only support themselves on advanced courses at times of change in their careers. Numbers of such people were few but not insignificant. However, there were too few to warrant continuation of a high level course with its commitment of staff, time and resources. To overcome this problem the course was offered part-time as well as full-time. This has proved an enormous success, the average number of students having been 50 for the past few years. Subject matter is split into two parts and each taught intensively on one day per week. Full-time students take both modules, part-timers take one in each of two consecutive years. In addition, considerable directed private study consolidates the relatively small amount of teaching time. Local industrial companies are enthusiastic about the scheme as many find that with the stimulus of the one day spent at University, five days' work is willingly and ably fitted into the remaining four!

A Microprocessor module has recently been added to the original pair and in 1981 a Micro-electronics module commenced. To these, a further module in Telecommunications course will soon be added. Following discussion with industry the Computer Engineering and Microprocessor modules will, next session, be combined as a single subject which reflects the advancing technology. Hence four specialist in-depth modules are offered, from which students select two and, in doing so, tailor the course to their own specialist interests and requirements and to those of their companies.

In this course, great emphasis is placed on practical work, theory being backed by experimentation at all stages. Students perform a three month full-time project at the end of the course, which includes technical and general planning, design, construction and evaluation work, a demonstration of understanding and a final technical report. Most projects are carried out in industry under joint university/industrial supervision, so enabling a student to introduce a novel approach, based on his studies, to a real-life industrial problem.
The taught M.Sc. described here has a high teaching efficiency, is practical in terms of release from work and is of low cost to industry. It goes a long way toward meeting the needs of companies in terms of updating, studying a related field and in-depth retraining.

5. SHORT COURSES

Courses of up to two weeks' duration are very attractive to industry as they can normally be accommodated in an industrial time scale with the minimum of disruption. They are the most popular way of gaining knowledge of a limited range of topics in a short time. They do, however, suffer from the disadvantage of being very intensive - particularly difficult for people unused to study - and have ill-defined starting points as attendees invariably come from different backgrounds with varying levels of prior knowledge.

Short courses that have recently been offered by the Electronic & Electrical Engineering Department include specialized courses in Microprocessor Applications, Digital Signal Processing and VLSI Micro-electronics, through to the very popular appreciation course 'Electronics for the Non-Specialist'. The last mentioned course has now run for some 10 years, consistently attracting the imposed maximum of 30 students. This reflects the increasing need of people from many disciplines to use and learn about electronic equipment and indicates the lack of coverage in many undergraduate courses. In line with emphasizing practical skills where possible, much of the time is devoted to design experiments, enabling students to learn through practice and enjoy the acquiring of new skills. Discussions, often long into the evening, sometimes result in novel applications of electronics which can lead to joint developments between industry and the university.

Most courses offered so far have stood alone or formed part of a very short series. No academic qualification has been offered at the end of courses so delegates come entirely out of a desire to learn. Short course activity is undoubtedly a future growth area and suggestions have been made at national level for short course credits to count towards a diploma. Such a move should be encouraged as courses will then be taken even more seriously and gain further industrial and, possibly, governmental support.

6. COLLABORATION RESEARCH DEGREES

The normal route to M.Phil. and Ph.D. degrees is by a full-time course, usually undertaken at university soon after graduation from the first degree. Like several U.K. universities, Surrey offers a collaborative scheme for students working in industry, provided the project is of an adequate standard and can be guaranteed to continue for the requisite time. Often the research work is conducted jointly by the university and company and several interested people, other
than the student and his immediate supervisor become involved. This interaction can do nothing but good; the cross-fertilization of ideas improves understanding and aids innovation via a thorough study of a topic of real interest to the sponsoring company.

7. STAFF INVOLVEMENT AND FUNDING OF CONTINUING EDUCATION COURSES

University resources which can be directed to continuing education are limited. Staff support is generally good, although those whose contribution would be most effected are, inevitably, those who are already heavily involved in undergraduate activities and research development. To gain an increase in effectiveness some re-orientation of university activities must occur and duplication, which we can ill-afford, must be avoided. Universities should offer courses which reflect their special expertise and will complement other activities: only then will they gain the full enthusiasm and support of the lecturers. Universities must ensure that suitable industrial staff contribute fully and make the liaison work well.

Since M.Sc. courses and collaborative research are activities recognized as integral parts of teaching, there are few problems with funding and resources. Short courses do not, regrettably, enjoy such a luxury. There is no government funding other than occasional pump-priming grants such as occurred recently for micro-processors. Short courses must be self-financing and so, must meet the needs of industry sufficiently well to attract students in reasonable numbers. At present, little recognition is given to academic staff in terms of promotion prospects and departmental funding, for their involvement in short courses. The present level of activity of many lecturers is, therefore, in recognition of a need rather than for personal gain, which makes it highly commendable. Programmes similar to those described in this paper will not develop to their full potential, despite their value to industry, without government support and it is to be hoped that this is recognized in future.

Continuing education, although gaining in importance, is still in its infancy. Universities, industry and government must all contribute to ensure that we use the personal resources and innovative skills of the engineer to full advantage throughout his career, and continue his education in breadth and depth well beyond first degree level.
A POST-ACADEMIC COURSE IN INNOVATION-MANAGEMENT AT THE DEPARTMENT OF INDUSTRIAL DESIGN ENGINEERING OF DELFT UNIVERSITY OF TECHNOLOGY

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ABSTRACT

At the Department of Industrial Design Engineering of Delft University of Technology, The Netherlands, a post-academic course in innovation-management has been designed and been run for the first time in 1981. The contents of the course are described, the course is evaluated and future improvements are discussed.

RESUME

A l'école d' "Industrial Design Engineering" de l'Université Polytechnique de Delft, Pays-Bas, on a organisé un cours de gestion de l'innovation. Les sujets traités sont décrits, le cours est apprécié et les intentions pour l'avenir sont discutées.

ZUSAMMENFASSUNG

Am Institut für "Industrial Design Engineering" der Technischen Hochschule Delft, Niederlände, ist ein Seminar für Innovationsmanagement organisiert worden im Rahmen der Kontinuierlichen Erziehung. Das Program des Seminars wird beschrieben, die Erfahrung damit wird gewertet und Pläne für die Zukunft werden erörtert.

1. INTRODUCTION

"Due to rapid progress of science and technology, continuing education has become essential for professional engineers, for industry and for society as a whole". With this statement opens prof. Krebs-Ovesen's recently published book on the continuing education of engineers. (N. Krebs Ovesen, 1980). In this important book, which gives an up to date treatment of the state of the art, both from the educational and the organizational viewpoint, also a survey is given of legal aspects concerning continuing engineering education in various countries. One of the systems described is the one currently in operation in The Netherlands (p 155 ff). For particulars of the system I refer to this description, but I recall that continuing education has received legal status in this country in
1975 and that coordinating units have been established in cooperation with the professional associations. These coordinating units will be the main administrative bodies, but the responsibility for the content and the structure of the courses remains with the universities. The professional association concerned with continuing engineering education is the Royal Institute of Engineers with headquarters at The Hague. Together with the technical universities this institute has established a number of coordinating units for various fields of engineering, amongst which one for post-academic education in mechanical engineering and related engineering disciplines. It is in this structure that the Department of Industrial Design Engineering of Delft University of Technology organized a post-academic course in innovation-management, which will be the subject of this paper.

The course is based on the department's experience with teaching innovation-management to undergraduate and graduate students. The main objective of the department is to educate industrial design engineers. They will be responsible for many of the innovative new products our manufacturing industries are going to offer to the market in the future. That our economies badly need innovative new products everybody is aware of nowadays. The present SEFI-conference is but one of the many symptoms of this awareness. Innovative new products presuppose innovative industrial design engineers. But that is not sufficient. The innovative process in our industrial enterprises has to be managed, well-managed in order to lead to economic success. Brian Smith has pointed to this very penetratively in a recent article (Smith 1981). The problem is not only to design a good new product, the problem is also and may be even in the first place to found a successful business around the new product. This raises the important problem of innovation management and every industrial design engineer should know the main features of innovation-management, whilst those who aspire to follow a management career in their discipline should study it in more detail. This is why at our department courses in innovation-management form part of the curriculum. For more details of this curriculum I refer to various other papers delivered at this conference, viz. by Schierbeek (Schierbeek 1982), Van Eyk (Van Eyk 1982), Marinissen and Roozenburg (Marinissen and Roozenburg 1982) and Eekels (Eekels 1982).

Now the study of innovation-management is a rather young discipline. It appears under various other names too like product-planning, new product-development, new business development, product-market strategy, design-management. Although at present the body of literature on it is already impressive and fastly increasing, 10 years ago the discipline was hardly existent. It is therefore evident that there will be a definite need for continuing education especially in this field. The aim of the course described is to partly satisfy this need.

The course lasts four days and is intended for all those who occupy key-positions in the management of the company's innovation-process,
eg. directors, managers of marketing-, R&D-, strategic planning-, productplanning departments and the like. Participants are expected to have finished an academic education or to possess a comparable level of knowledge. Participation is limited to 25.

2. DESCRIPTION OF THE COURSE

The objectives of the course were formulated as follows:

a. to give participants a survey and analysis of the process of product-innovation in the company;

b. to give participants insight into the character, the scope and limits of the methods that are available to promote and improve this innovation process. More specifically attention will be paid to - product strategy formulation and productplanning; - the decision structure in the innovation process;

c. to give participants some exercise in problemsolving with respect to this innovation process.

The course consists of lectures and exercises.

The lectures follow in principle the structure of the innovative process as depicted in fig. 1 (Eekels 1981), but with emphasis on the left hand part of that figure.

- General Introduction

On the basis of a structural analysis of industrial action the problem area is mapped. The role of corporate policy and planning is illustrated after which the industrial innovation process is exposed in main lines. In this process the essential elements are policy formulation, idea finding, strict product-development and realization. The concept of corporate policy is analysed and defined in an operational way. Corporate policy consists of corporate objectives on the one hand and of strategies on the other hand. The main point in the formulation of corporate policy.
lies in the formulation of the strategies. This also is by far the most difficult point.

b The basic strategy formulation cycle

The basic strategy formulation cycle begins with an objective analysis of the present situation of the company. How will the company develop if we keep to our present policy? In many cases the answer will be unsatisfying and then the question is raised whether a policy change (which mostly means a change in strategies) can bring about improvements. First an internal and an external strategic analysis have to be performed to serve as starting points for the formulation of a new policy. The various methods for policy formulation (which mainly boils down to the formulation of new strategies) are presented. Also the shift from strategic planning towards strategic management is discussed.

c Product strategy

The hard core of the newly formulated corporate policy should be a new product-strategy. The various elements of product-strategy are discussed, amongst which the product-marketing-strategy and the criteria for idea finding regions. Policy formulation is an iterative process, constantly requiring decisions. The arguments for those decisions are not always (or even seldom) of a rational and objective character. A collection of irrational criteria is presented.

d Idea finding

Where do ideas for new products come from? A number of possible sources for product ideas is discussed. It is useful to perform the idea finding process in two steps, firstly establishing the main direction for the search by defining idea finding regions and secondly generating the product ideas proper.

e Evaluation and selection of ideas

Not all ideas for new products deserve to be developed further. One has to select the most prospective ones and this presupposes evaluation of the ideas brought forward. Rational methods for this evaluation- and selection-process are presented.
Productplanning

In most companies several new product-developments occur simultaneously. In order to manage the overall innovative process in the company a new function, the product planning function is lately emerging beside the product development function. Four tasks are assigned to productplanning as understood here, viz. product-strategy-formulation, idea finding, control of strict product development and product survey (in the market). The organization and the instruments of the productplanning-function are discussed.

Organization-development

Innovation means change, and change meet with all kinds of emotional resistance. It is therefore not sufficient to argue the change on rational grounds only: people have to emotionally accept that the plans worked out offer better perspectives for the future indeed. Organization-development is the discipline that deals with these kinds of organization-psychological questions, and the main contributions of this discipline to the corporation's innovative process are discussed.

The lectures were supplemented by discussions and by a few exercises.

3. ORGANIZATION OF THE COURSE

The course was given during four subsequent days at the premise of the department, 6 hours per day. Of the 24 hours available 12 were used for lectures, 6 for exercises, 4 for discussions, 1 for an excursion to the laboratories of the department, and 1 for the opening ceremony and administrative matters. The course fee was 775 Dutch guilders, including course material, lunches and drinks. The course has been given once up to now, but will be given again in the fall of 1982.

The faculty consisted of the staff of the section for Industrial Engineering of the Department of Industrial Design Engineering at Delft University of Technology. Most of the participants came from industry. 82% of them had completed a university or college-education. 55% of the participants were between 30 and 45 years old, 76% of the participants stated that they had enrolled because societal changes require new professional skills that had not been taught to them during their formal education.
4. EVALUATION OF THE COURSE

Participants were requested by the coordinating unit to fill out an evaluation form. They were unanimously enthusiastic about the course. The form contained 25 questions and in all of them the course scored high to very high. Of course we are very pleased with that result. Yet there were a few points of criticism and a number of desiderata. The criticism mainly pertained to the exercises. On the one hand it was stated that participants had profited more from the lectures than from the exercises, but on the other hand there was a rather strong request to pay more attention to practical application of the theory by means of exercises. As the exercises partly were taken from the material we use for our students we concluded from this that for the more experienced participants of a post-academic course more sophisticated exercises should be constructed. Among the desiderata we consequently find a demand for more (and better) exercises and for an explicit treatment of the strict-product development process. The next course will take account of these desiderata.

5. ACKNOWLEDGEMENTS

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EXPERIENCES OF THE COURSE ACTIVITIES AT THE UNIVERSITY OF OULU

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ABSTRACT

In this contribution the course activities of the University of Oulu in Northern Finland are described and the experience gained is discussed.

The course activities of the University of Oulu started in 1978 and are almost totally financed by the state through the Ministry of Labor.

In the course program an attempt has been made to combine the following objectives:

1. to employ the unemployed diploma engineers and other graduated students from the University of Oulu or from other universities in Finland
2. to advance the development of the industry in Northern Finland
3. to create new jobs for engineers mainly in the small businesses of Northern Finland
4. to create new job opportunities for other people in small businesses in Northern Finland.

The preliminary results of the activities are discussed in detail. Some of the preliminary findings are:

1. the integration of employment of graduated engineers and the active improvements of the employment situation in the surrounding region can be combined.
2. the means making this combination possible is project training or learning by doing.
3. the success of the integrated approach requires a great amount of planning and sufficient financing
4. the activities will have an effect on the basic engineering education.

The results of the course activities clearly indicate the following needs in the basic training of engineering students:

1. the need for more project work and economical studies
2. the need for going from training by disciplines to the systems approach
3. the need for basic human training in team work, human communications and personal development.
Based on experience in basic engineering training and the recent course activities a model for the engineering education for universities serving developing regions is presented by the another. Finally this type of engineering training is discussed.
ADAPTATION D'ENSEIGNEMENT SUPÉRIEUR À LA FORMATION CONTINUE DES CADRES TECHNIQUES DANS LES PAYS EN VOIE DE DÉVELOPPEMENT

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ABSTRACT

After the end of regular studies, the science and technology have made in the meantime big steps ahead and have been advanced quickly. Consequently, the knowledge acquired during the regular studies became more or less obsolete; therefore, one prolonged and continuing higher education is imposing.

This complex problem is usually solved in the developed countries by the organization of normal postgraduated studies for the diverse disciplines necessary to given specialization, because the number of interested students is, as a rule, considerable.

On the contrary, in the developing countries this number is strongly restricted; the same is in the case of needed specialities. Therefore, at this situation, it is more indicated for the engineer-students to undertake the postgraduated studies without leaving off the own job.

These studies must have a special form, that is they must be guided by one moderator assisted by a group of adequate high specialists.

The volume and duration of such a type of postgraduated studies, according to already acquired experience, ought to have about 200 hours during two years and that for a maximum of seven different profounded disciplines. The author gives one example (already realized and verified) of the organization of the described type of studies.

RESUME

Après la fin d'études régulières, la science et la technologie correspondantes ont fait des grands pas en avant et se sont surement développées très vite; par conséquent, les connaissances acquises pendant les études régulières sont devenues plus ou moins caduques, ce qui impose comme indispensable l'enseignement supérieur prolongé et continu.

Ce problème complexe se résout dans les pays développés, habituellement, par l'organisation normalisée d'études postdiplômes (ou du troisième cycle) pour des diverses disciplines, nécessaires à une spécialisation donnée, parce que le nombre d'étudiants est, en règle
générale, suffisamment grand. Au contraire, dans les pays en voie de développement il s'agit du nombre très restreint de tels candidats ainsi que des spécialités fortement limitées en quantité.

C'est pourquoi, dans ces cas-ci, il est plus indiqué que les études postdiplômes soient entreprises parallèlement avec le travail que les ingénieurs-étudiants ne l'interromperont pas. Ces études, donc, doivent avoir une forme spéciale, c'est-à-dire être des études guidées par un modérateur secondé par un groupe de hauts spécialistes correspondants.

L'ampleur et la durée de ce type d'études postdiplômes, à la base d'expérience déjà acquise, se sont fixés à un nombre d'heures d'environ 200 au cours de deux années et ceci pour un maximum de sept disciplines différentes approfondies. L'auteur donne un exemple (déjà réalisé et vérifié) de l'organisation des études du type décrit.

ZUSAMMENFASSUNG

Nach der Beendigung der ordentlichen Studien haben die Wissenschaft und die entsprechende Technologie schon einen weiteren Fortschritt gemacht und so werden die während der ordentlichen Studien erworbenen Erfahrungen ungenügend. Deswegen wird eine dauernde Fortbildung unentbehrlich.

Dieses komplizierten Problem wird in den schon entwickelten Ländern gewöhnlich durch die Einrichtung der vorgeschriebenen Postdiplomstudien für verschiedene Fächer (die für die gewünschte Fortbildung notwendig sind) gelöst, da die Zahl der interessierten Postdiplomstudenten in der Regel ziemlich hoch ist. Im Gegenteil handelt es sich in den Entwicklungsländern um eine kleine Zahl solcher Postdiplomstudenten und auch um eine begrenzte Zahl notwendiger Fächer. In solchen Fällen ist daher zweckmässiger, dass die jungen Ingenieure, die sich weiter bilden wollen, es neben ihren normalen Tätigkeiten unternehmen, das heisst, nicht nur zu studieren, sondern auch im Dienst zu sein.

Diese Studien müssen, also, eine spezielle Form haben, das heisst, sie sollen von einem Mentor und mit der Hilfe mehrerer hoher Fachleute geleitet werden.

Der Umfang und die Dauer der Postdipolomstudien solchen Charakters sollen nach schon gewonnenen Erfahrungen, während zwei Schuljahre ungefähr 200 Lehrstunden haben und zwar für insgesamt höchstens sieben verschiedene gründlich ausgearbeitete Fächer.

Der Autor gibt ein Beispiel der Einrichtung des beschriebenen Modells der Postdipolomstudien, das schon geprüft und durchgeführt ist.
Il est bien connu que le progrès du monde et de l'humanité dépend de plus en plus de l'avancement de la science et de ses produits, parmi lesquels se trouvent, comme très importants, la technique et la technologie de la production industrielle.

Par conséquent, chaque pays (et d'autant plus celui en voie de développement) a des besoins impératifs à produire des ingénieurs et des techniciens de diverses spécialités.

Cependant, la formation de cadres demande, en outre du bon personnel enseignant, des méthodes satisfaisantes d'enseignement et des laboratoires bien équipés dans les centres scolaires, un temps indispensable prévu pour les études régulières, qui s'étend entre trois et cinq ans.

Les plans et les programmes de cours, même s'ils sont contemporains et modernisés, ils ne changent que très rarement pour une génération donnée d'étudiants. Pendant ce temps-là, cependant, l'avancement de la science et de la technique s'était produit encore plus loin. Ainsi, la connaissance de cette génération, acquise à l'école ou à l'université, doit se montrer partiellement déjà caduque. L'intervalle de temps que cela se fait sentir se raccourcit de plus en plus.

Tout ceci parle de l'indispensabilité de l'enseignement continu des cadres techniques, si ceux-ci désirent être au cours de l'avancement de leurs professions et de participer activement dans les travaux et au développement de leurs entreprises professionnelles et de leur ambiance vitale en général.

En ce qui concerne l'enseignement du cadre technique, on peut dire que chaque profession prévoir certaines disciplines fondamentales qui servent de base du perfectionnement professionnel ultérieur. Ces disciplines ne changent pas si vite; elles restent normalement dans le processus d'enseignement même assez longuement inchangées. Les disciplines plus spécialisées changent déjà plus vite leur structure et leur contenu, mais on ne pourrait pas les alterer essentiellement au cours d'études d'une génération d'étudiants.

Donc, le seul moyen de suivre, au cours d'études, l'avancement irresistible de la science et de la technique correspondante, consiste à l'introduction, vers la fin d'études régulières, des disciplines très spéciales comme des cours d'option, ce qui aurait permis de les changer chaque année si cela est nécessaire ou même de les abandonner s'ils s'avèrent déjà caduques.

Ce système-ci nous paraît, pour le moment, le seul qui, en certaine mesure, puisse diminuer la différence entre le niveau, l'ampleur et la profondeur des connaissances acquises au cours d'études régulières et les mêmes caractéristiques, correspondantes à leur état réel développé entretemps dans le monde. Naturellement, le problème n'est pas résolu définitivement ainsi, car après les études finies, après avoir reçu le diplôme de la faculté, l'ingénieur rencontre bientôt avec le fait que la science et la technique de sa profession ont effectué des pas considérables en avant même plus rapidement qu'au cours de ses études régulières.
Il faut conclure, donc, que les techniciens et les ingénieurs, s'ils veulent suivre cet avancement, doivent entreprendre l'enseignement ultérieur qui ne pourrait pas, naturellement, avoir la même forme que celle prévue pour les études régulières. D'autre part, il faut tenir compte que les techniciens et les ingénieurs diplômés se trouvent, en règle générale, déjà engagés par des organisations de travail et que ces gens-là ne peuvent ou ne désirent même pas les abandonner pour étudier de nouveau à la façon usuelle.

Ils restent, alors, des études supplémentaires (parallèlement avec le travail régulier) organisées par les centres professionnels d'enseignement - des écoles supérieures et des facultés ou des institutions correspondantes, car les études individuelles, même à l'aide de littérature la plus nouvelle, ne peuvent pas donner des résultats satisfaisants.

Par conséquent, il faut organiser des cours de spécialisation et de perfectionnement (de durées différentes) au sein des écoles correspondantes, mais aussi avec la participation non seulement du personnel provenant de l'école en question, mais de gens recrutés d'institutions des recherches scientifiques et même d'organisations industrielles plus développées. La composition de ce team de hauts spécialistes, dépendra, naturellement, du profil nécessaire à la spécialisation demandée.

Comme il s'agit habituellement, d'un nombre restreint de tels ingénieur-étudiants, pour lesquels se fait sentir le besoin urgent dans les pays en voie de développement, il n'est pas opportun d'organiser un entier processus régulier. Le seul moyen rationnel, dans ce cas-ci, consiste à l'organisation d'études postdiplômes (ou du troisième cycle), mais du type guidées par un modérateur (en latin dit mentor). Ce type d'études est de loin plus élastique et moins couteux que celui d'études postdiplômes normalisé, avec des cours et des travaux pratiques prévus par avance. Ledit type d'études s'adapte plus facilement, beaucoup mieux et plus vite aux besoins réels des pays en voie de développement.

Ces études postdiplômes peuvent, d'une façon adéquate, suivre les besoins spécifiques concernant le cadre professionnel du niveau supérieur, qui serait (dans un interval de temps prévu) indispensable au développement plus rapide et sans obstacle, désiré par le pays voulant utiliser ses ressources naturelles et son potentiel humain.

Le recrutement d'étudiants qui auraient suivi les études du type mentionné, doit être effectué par la voie du concours, mais il faudrait aussi tenir compte de voeux et de besoins des organisations qui, par exemple, ont l'intention d'envoyer ses gens à l'innovation de leurs connaissances professionnelles et de participer au financement de leurs études.

L'adaptation d'études postdiplômes du type décrit concerne, en outre le profil spécialistique en général, le choix précis des disciplines scientifiques spéciales, ainsi que des programmes de la spécialisation correspondante. Naturellement, la quantité de la matière étudiée ne devrait pas passer la limite qui avait été
conditionnée par les connaissances acquises auparavant et pas la durée prévue d'études postdiplômes, qui s'étendra usuellement d'un à deux ans, étant donné que l'étudiant ne pourra pas consacrer tout son temps exclusivement aux études.

Comme l'illustration de l'ampleur et de la physionomie d'un profil spécialisé d'études préconisé ici, nous allons citer la spécialité de la métrologie et de la technologie de mesures électroniques. Dans la première année d'études, l'étudiant est chargé d'approfondir ses connaissances concernant la théorie de probabilité et de la mathématique statistique. Ces bases scientifiques lui auront servi à l'étude de la théorie des erreurs et d'élaboration des résultats de mesure. La deuxième année est consacrée à l'étude des bases mêmes de la spécialisation, qui sont: la métrologie générale, puis l'électrométrie et ensuite la métrologie des grandeurs nonélectriques. A la fin d'études, l'étudiant doit choisir un ou deux de cours d'option, par lequel il va approfondir la discipline dans laquelle il pourra ultérieurement trouver un sujet intéressant pour élaborer sa thèse finale. Comme exemples de ces cours d'option on pourrait mentionner, entre autres, les cours suivants: l'automatisation de mesures, les mesures de grandeurs variables de façon stochastique, l'application de la théorie d'information en métrologie, la fiabilité d'éléments et de systèmes de mesure, l'organisation du contrôle de la qualité des produits.

Si toutes ces disciplines auraient été enseignées de la façon usuelle, comme cela se fait dans les pays développés, c'est-à-dire par l'organisation des cours et des travaux pratiques prévus dans un plan fixé par avance pour un groupe d'étudiants qui auraient régulièrement fréquenté ces cours, la durée serait semblable à l'enseignement de sept cours différents avec deux heures par semaine chacun. Ceci fait, au total, environ 200 heures pendant toute la durée d'études postdiplômes.
There is no doubt today that engineers have to acquire knowledge and abilities in social sciences. Uttered and unuttered the impression arises as if the qualifications in social sciences had not been necessary in former times for an engineer who supposedly was only interested in technical process and didn’t take consequences of his inventions into consideration. However it is shown that already since the turn of the century the social, political and ethical responsibility of the engineer has been clearly seen. Since 1900 at the latest engineers have to attend lessons in social sciences in order to understand to what degree their work is dependent on other problems. Therefore there has not been a fundamental change in profession and training of the engineer.
diese Qualifikationen für den Ingenieur in früheren Zeiten nicht nötig gewesen; der Ingenieur war damals angeblich ein reiner Fachmann, der nur den technischen Fortschritt im Auge hatte und sich um die Folgen seiner Entwicklungen nicht kümmerte. Demgegenüber wird nachgewiesen, daß schon seit der Jahrhundertwende die soziale, politische und ethische Verantwortung des Ingenieurs klar erkannt worden ist. Spätestens seit 1900 müssen Ingenieure im Studium Lehrveranstaltungen in Sozialwissenschaften besuchen, um die Abhängigkeit ihrer Tätigkeit von übergreifenden Zusammenhängen zu erkennen. Von einem grundlegenden Wandel in Beruf und Ausbildung des Ingenieurs kann also nicht die Rede sein.


- in seiner Tätigkeit ökonomische und ökologische Gesichtspunkte zu beachten,
- das soziale Umfeld sowie die Arbeitsbedingungen und Abläufe seines Betriebes zu berücksichtigen,
- die politischen und gesellschaftlichen Auswirkungen der von ihm geschaffenen Technologien zu bedenken,
- sich der Maßstäbe technischen Fortschrittes und einer moralischen und ethischen Verantwortung bewußt zu sein.

Durch empirische Untersuchungen ist nachgewiesen, daß 80% der genannten Fähigkeiten und Kenntnisse erst im Beruf - sei es durch praktische Tätigkeit sei es durch Weiterbildung - erworben werden. Da diesen Kenntnissen jedoch ein hoher Stellenwert für die Ausübung des Berufes zukommt, wird von den Ingenieuren selbst vorgeschlagen, den Anteil der Fächer im Studium in folgender Weise zu verändern 1):

- Ingenieurwissenschaften 47% statt 55%.
- Mathematik und Naturwissenschaften 30% statt 34%.
- Sozialwissenschaften 23% statt 11%.

1) Studium, Beruf und Qualifikation der Ingenieure (1979) S. 59ff.
Die allgemeinbildende Qualifikation soll also verdoppelt werden und zwar zu Lasten der Grundlagenfächer und der fachlichen Ausbildung.

So läßt sich das ideale Qualifikationsprofil eines Ingenieurs folgendermaßen skizzieren: fachlich qualifiziert, wirtschaftlich handelnd, gesellschaftsbewußt, verantwortungsvoll. Seine volle Schärfe, Berechtigung und Dringlichkeit gewinnt dieses Profil erst vor dem Hintergrund der gegenwärtigen und zukünftigen Lebensverhältnisse. In Übereinstimmung mit der modernen Curriculumtheorie wird die Qualifikation des Ingenieurs aus der Notwendigkeit abgeleitet, die Lebensqualität von heute zu sichern und die drohenden Aufgaben der Zukunft zu bewältigen; als solche gelten z.B. Beherrschung moderner Waffensysteme, Versorgung mit Rohstoffen und Energie, Beseitigung von Hunger und Armut, Entwicklung von Nachrichten- und Verkehrssystemen, Humanisierung der Arbeitswelt, Automatisierung etc.

Indem die Ausbildung und Qualifikation der Ingenieure auf die aktuellen und zukünftigen Lebensbedingungen ausgerichtet wird, ergibt sich, daß das Qualifikationsprofil den Charakter von etwas Neuartigem und Modernem sowie Einmaligem und Erstmaligem erhält. Dies wird deutlich an Formulierungen wie: "Es reicht heute nicht mehr aus, daß der Ingenieur etwas tun kann..."; "die heute vorfindliche Komplexität der Probleme in unserer Gesellschaft"; "bisher haben... Ingenieure... versucht, durch Reduktionen und vereinfachende Modellbildungen, komplexe Probleme und Systeme bearbeitbar zu machen"; "Mehr denn je benötigte der Maschinenbau... Ingenieurnachwuchs, der die... anspruchsvollen Aufgaben der Zukunft lösen kann".

Indirekt wird dadurch die Qualifikation des Ingenieurs von heute und morgen als völliges Gegenteil des Ingenieurs von gestern beschrieben. Teils ausgesprochen, teils unausgesprochen wird unterstellt, daß dieser ein spezialisierter Wissenschaftler gewesen ist, der die Bearbeitung übergreifender Probleme an der Bearbeitung übergreifender Probleme anderer Fachleute überließ, der als interessenneutraler Spezialist in seinem Fach nur die technische Entwicklung im Auge hatte, ohne an die Folgen für die Gesellschaft und die Umwelt zu denken. Für diesen war der technische Fortschritt nicht aufhaltbar und auch nicht Gegenstand von Kritik, denn dieses bedeutete Kritik am herrschenden System und dies war nicht Aufgabe des Ingenieurs. So wird das Bild eines Technikers gezeichnet, der kompetent aber beschränkt, aktiv aber folgsam war; er galt als intelli-

2) Ingenieure für die Zukunft (1980) S.30 (Hervorhebung v. Verf.)
3) Fächerübergreifende Lehre für die THD (1981) S.12 (Hervorhebungen v. Verf.)
4) Anforderungen an Maschinenbauer (1980) S.458 (Hervorhebungen v. Verf.)
gent in seinem Fach und verband ein Maximum an Wissen mit einem Minimum an gesellschaftlichen Interessen und Kenntnissen\textsuperscript{5}).

Es soll an dieser Stelle nicht untersucht werden, warum gern und nachdrücklich dieses düstere Bild des Ingenieurs von gestern gezeichnet wird, und warum es immer wieder als Folie für die Forderung nach Reform der Ingenieurausbildung benutzt wird; uns geht es hier um die Frage, ob die Qualifikation des Ingenieurs in früherer Zeit tatsächlich so grundlegend anders gewesen ist, daß von einem Wandel in Beruf und Ausbildung gesprochen werden kann.

Spätestens zu Beginn dieses Jahrhunderts entstand in den Technischen Hochschulen, in den Fachverbänden und Kultusverwaltungen eine rege Diskussion darüber, ob und in welcher Form die Ausbildung des Ingenieurs im Hinblick auf die beruflichen Anforderungen reformiert werden sollte. Ein von Verband Deutscher Architekten- und Ingenieurvereineingesetzter Ausschuß untersuchte den Anteil der verschiedenen Fachgebiete am Gesamttudium und kam in einer 1910 vorgelegten Denkschrift "Rechts-, Staats- und Wirtschaftswissenschaften an den Technischen Hochschulen" zu folgender Bestandsaufnahme\textsuperscript{6)}:

Im Studienjahr 1908/09 entfielen für das vierjährige Studium der Bauingenieure im Durchschnitt aller Technischen Hochschulen auf die

- ingenieurwissenschaftlichen Fächer: 3418 Std. (76%)
- mathematisch-naturwissenschaftlichen Fächer: 936 Std. (21%)
- sozialwissenschaftlichen Fächer: 136 Std. (3%);

für das Studium der Architekten lautete die entsprechende Verteilung:

- Ingenieurwissenschaften: 4364 Std. (86%)
- Mathematik und Naturwissenschaften: 578 Std. (11%)
- Sozialwissenschaften: 172 Std. (3%).

Interessant ist, daß das Stundenvolumen der Sozialwissenschaften von Hochschule zu Hochschule erheblich differierte: bei den Bauingenieuren lag Hannover mit nur 36 Std. am niedrigsten, während Karlsruhe mit 342 Std. weit vor Aachen (264 Std.) und Dresden (228 Std.) die Spitze hielt. Auch bei den Architekten hatte Karlsruhe mit 280 Std. den höchsten Anteil vor Aachen (252 Std.), Hannover (228 Std.) und Berlin (222 Std.); Darmstadt lag mit 72 Std. am niedrigsten. hinter Stuttgart und München (jeweils 114 Std.).

\textsuperscript{5)} vgl. Rimbach (1979) S.482 und Anm. 3 a.O.
\textsuperscript{6)} Verband Deutscher Architekten- und Ingenieurvereine (1910) S.7ff.
Zusätzlich zu diesen obligatorischen Stunden wurden zwar noch fakultative Lehrveranstaltungen in Volkswirtschaftslehre, Recht, Philosophie, Pädagogik, Hygiene etc. angeboten; diese wurden jedoch von den Studenten nur sehr wenig genutzt, so daß die Autoren der Denkschrift zu der Erkenntnis kamen: "Durch den intensiven Betrieb der mathematischen, naturwissenschaftlichen und rein technischen Fächer werden die Studierenden zu ihrem eigenen Schaden zum größten Teil abgehalten, sich den ergänzenden Wissenschaften der Rechts- und Wirtschaftslehre zuzuwenden".

In diesen Worten kommt deutlich zum Ausdruck, daß die sozialwissenschaftlichen Fächer um 1900 im Ingenieurstudium einen viel zu geringen Stellenwert hatten und daß es darauf ankam, diese Relation zu verändern. Folglich schlug der Verband Deutscher Architekten- und Ingenieurvereine vor, das Volumen der sozialwissenschaftlichen Fächer von 136 auf 288 Stunden, also um 100% zu erhöhen, so daß der Anteil dieser Studieninhalte von 3% auf 6% stieg. Für die Ausbildung der Architekten, die später in den Staats- und Kommunaldienst eintreten wollten, wurden ebenfalls 288 Stunden - statt bisher 172 Stunden - für sozialwissenschaftliche Inhalte empfohlen, so daß hier der Anteil dieser Fächer nun 5,61% statt 3% betrug.

Diese erhebliche Steigerung der nichttechnischen Fächer sollte jedoch nicht zu einer Verlängerung der Studienzeit oder zu einer Erhöhung der Wochenstundenzahl führen sondern durch eine Verringerung der mathematisch-naturwissenschaftlichen und ingenieurwissenschaftlichen Fachstudien sowie durch eine verbesserte Vorbildung der Studienanfänger auf den Gymnasien verwirklicht werden.

Für das Studium der Ingenieure galten vor allem folgende nichttechnischen Fächer als bedeutsam:
- Wirtschaftswissenschaften, insbesondere Volkswirtschaftslehre und -politik; für die Bauingenieure speziell Verkehrs- und Finanzwirtschaft, Bank- und Börsenwesen, Boden-, Bau- und Wohnungspolitik.
- Rechtswissenschaft, davon besonders BGB, Baurecht, Handelsrecht, Wechselrecht sowie Sozialgesetzgebung.

Oberflächlich gesehen lag die Funktion dieser Fächer darin, daß sie den Ingenieuren die für den Beruf und das Leben notwendigen Kenntnisse und Fachinformationen vermitteln sollten; als wesentlicher Grund wurde jedoch hervorgehoben, daß die fachübergreifenden Verflechtungen und Bezüge der Ingenieurarbeit...
eine nichttechnische Qualifikation erfordern, denn "dem Ingenieur Volkswirtschaftslehre und Volkswirtschaftspolitik vorenthalten, heißt behaupten, daß man die Folgen der eigenen Tätigkeit nicht zu kennen brauche" heißt es schon 19038).


Daraus läßt sich ablesen, daß der Ingenieur um die Jahrhundertwende gesehen wird nicht als ein interessenneutraler Spezialist, nicht als ein nur an der technischen Entwicklung interessierter Experte, nicht als ein unkritischer Fachmann, den die sozialen und gesellschaftlichen Folgen seiner Tätigkeit gleichgültig lassen. Vielmehr zeichnet sich aus dem vorliegenden Quellenmaterial das Bild eines Technikers ab, der die sozialen und wirtschaftlichen Zusammenhänge berücksichtigt, der sich der moralischen und ethischen Verantwortung seines Berufes bewußt ist und der seine Abhängigkeit von rechtlichen und ökonomischen Rahmenbedingungen kennt.

Dieses Qualifikationsprofil unterscheidet sich nicht prinzipiell von dem, das für den Ingenieur von heute oben skizziert worden war. Was Beruf und Ausbildung des Ingenieurs angeht, so gilt für heute wie für früher, daß die fachspezifische Qualifikation ergänzt werden muß durch eine sozialwissenschaftliche

8) Koehne (1910) S.7
9) Verband Deutscher Architekten- und Ingenieurvereine (1910) S.5
Ausbildung. Auch wenn seit der Jahrhundertwende in quantitativer Hinsicht eine Veränderung der betreffenden Studienanteile zu beobachten ist, so kann in qualitativer Hinsicht von einem prinzipiellen Wandel in Beruf und Ausbildung des Ingenieurs nicht die Rede sein.

LITERATUR


L'ESPRIT DE CREATIVITE A L'ECOLE NATIONALE SUPERIEURE DES
TELECOMMUNICATIONS DE BRETAGNE

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ABSTRACT

A "Grande Ecole" in France, built far from Paris on a remote campus, must find itself faced with a number of special problems.

The permanent contact between students, staff and the Directors of the School enables the students' aspirations to be more easily detected.

The fact that the School is new (it was founded in 1977) has made communication with industrialists of primary importance. In fact, the industrialists are members of the different teaching committees and can, thus, express their own expectations.

The creation of a large number of sporting, scientific and cultural clubs has enabled a large number of students (especially those from abroad) to develop other extra-curricula capacities during weekends or even during vacations.

A dynamic Junior Business Section and the creation of a large number of personal study projects (TEP) have, with the clubs, reinforced the idea of creativity in our School.

In order to extend its local and regional influence, the ENST BR has instigated the constitution of an association which has brought together such institutions as the CNEXO (Brest), the UBO (Brest), the UHB (Rennes), the IRISA (Rennes), and the CNET (Lannion and Paris). Local industrialists are also members of the association, which enables fruitful exchanges of researchers (whose fields of interest vary) to take place. The association also enables these researchers to join in applied research projects, which almost always lead to concrete results, thus developing the idea of innovation.

Within the framework of the policy of regionalisation presently being undertaken in France, the ENST BR can play an active rôle in advising and helping small-to-medium sized companies and industries. This field of activity can be extended to a national level leading to the final objective of: "A 'Grande Ecole' serving the nation".

ZUSAMMENFASSUNG


Der standige Kontakt zwischen Studenten, Lehrkörper und Direktion erlaubt es die vielseitigen Anliegen der Studenten besser zu erkennen.
Die Tatsache, dass diese Schule so jung ist (sie wurde 1977 gegründet) macht einen Austausch mit den Industriellen unumgänglich. Letztere haben ihre Vorstellungen und Erwartungen an den verschiedenen pädagogischen Kommissionen und Komitees, an denen sie vertreten sind, Ausdruck geben können.

Weiterhin wurden an der ENST BR zahlreiche Klubs gegründet (sportliche, kulturelle, wissenschaftliche), um den Studenten an Wochenenden, bzw. in den Ferien (vor allem für ausländische Studenten) persönlichkeitsbildende Freizeitbeschäftigungen zu bieten.

Im Zusammenhang mit diesen Klubs besteht die "Junior Entreprise" (Firmenmodell) und die Verwirklichung zahlreicher persönlicher wissenschaftlicher Projekte (TEP), welche an unserer Schule den schöpferischen Geist zum Ausdruck bringen.

Darüberhinaus hat die ENST BR an der Gründung einer wissenschaftlichen Interessen-gemeinschaft mitgearbeitet, um ihren lokalen und regionalen Einfluss auszudehnen. Zu dieser Gruppe gehören das CNEXO (Brest), die UBO (Brest), die UHB (Rennes), das IRISA (Rennes), das CNET (Lannion und Paris) sowie auch ortsansässige Industrien. Diese Interessengemeinschaft begünstigt den Ideenaustausch unter Forschern der verschiedenen Institute, regt Zweckforschung an und stärkt den innovativen Geist.

Die ENST BR kann also im Zusammenhang mit der aktuellen Regionalisierungspolitik ihre Rolle als wissenschaftlicher Ratgeber für kleine und mittlere Firmen und Industrien bestens ausüben. Diese Rolle sich natürlich noch weiter entwickeln, um das endgültige Ziel zu erreichen: "Eine Grande Ecole im Dienste der Nation".

Quelques mots tout d'abord pour vous présenter cette école et insister sur quelques unes de ses caractéristiques fondamentales.

L'ENST DE BRETAGNE a été créée en 1977. Elle a donc tout juste 5 ans d'existence. Elle héberge sur un campus de 22 ha situé aux environs de Brest, en bordure de mer, une population d'élèves dont le nombre ne doit pas dépasser 350 et qui proviennent à 60 % d'entre eux des classes de mathématiques spéciales M, P' et TA, après avoir réussi le concours dit Mines-Ponts-Télécoms. 20 % sont issu de la Formation Promotionnelle (DUT, BTS et 3 ans au moins de vie active), 20 % ont des maîtrises MST, EEA. Cette école est école d'application de l'Ecole Polytechnique.

Il s'agit donc de ce que l'on appelle en France, une grande école et sa création repose sur les données suivantes que nous avons scrupuleusement suivies pour la créer. Quelles sont les attentes des élèves qui désirent intégrer l'ENST DE BRETAGNE.

Ces motivations peuvent être classées en 2 catégories. Chaque élève sortant d'une "prépa" intègre dans une école qu'il a choisie en 2e ou 3e position pour ne pas redoubler son année.

Il y recherche une certaine détente voire une détente certaine, la sécurité de son diplôme, donc la relative simplicité des cours, l'assurance d'un bon résultat, c'est-à-dire un emploi sûr, bien rémunéré, donc d'avenir.
Ensuite ceux qui ont choisi l'ENST DE BRETAGNE pensent que son enseignement se classe dans des domaines en pleine expansion :
électronique, informatique, télécommunications, télématique, bureautique, robotique, etc, domaines dans lesquels ils seront sûrs de trouver un emploi. En effet, chaque ingénieur diplômé n'à qu'à choisir entre 5 à 7 postes qui lui sont offerts.

En outre, le travail qui correspond à ces emplois est intéressant par nature même : analyses des systèmes, études d'ensembles, réalisations techniques, parties économiques et financières...,
- par les responsabilités qui s'y rattachent,
- par les contacts qu'ils ménagent en France et à l'étranger.

L'étudiant de l'ENST BR a la possibilité de se démarquer des autres grandes écoles. Son profil de sortie est différent. Il peut donc, plus peut-être qu'ailleurs, se réaliser, joindre théorie et pratique, opter pour des spécialités plus adaptées à ses goûts, se "faire plaisir" dans des clubs scientifiques, sportifs ou sociaux.

Il cherche en outre un droit à sa responsabilité personnelle et collective dans le déroulement de son cursus, sa vie socio-culturelle, sa vie professionnelle.

Il veut le droit à l'innovation par des réalisations judicieuses qu'il effectuera lui-même, mais aussi grâce au mélange des populations qu'il côtoie, universitaires, jeunes sortant d'usines, étrangers.

L'ENST DE BRETAGNE est en effet la seule grande école du concours commun, Mines-Ponts à avoir suscité un tel mélange d'élèves.

Une telle formation correspond-elle aux attentes des industriels. Oui sans doute. Ceux-ci bien sûr recherchent des qualités fondamentales chez nos élèves : une bonne préparation de base à l'analyse permettant d'assimiler rapidement d'autres concepts, de connaître d'autres réalisations, de savoir procéder à la synthèse de divers courants de pensée, d'aboutir à des conclusions et à des décisions.

L'industriel veut que le jeune ingénieur sache mener son groupe qu'il ait un profil adéquat, que son utilisation complète soit la plus rapide possible.

Il veut aussi que cet ingénieur frais émoulu fasse preuve d'initiative et de créativité.

Pour toutes ces raisons, l'ENST DE BRETAGNE a été dotée des particularités suivantes.

Tout d'abord, 20 à 30 % du temps dévolu à la technique se fait en laboratoires et ceci sous deux formes principales.
- D'une part, des travaux pratiques classiques avec rédaction à chaque fois d'un rapport, en électronique, microprocesseurs, informatique, télécommunications,
- d'autre part, des travaux d'études personnels pendant lesquels les élèves sont peu guidés (30 % du temps total). Durant ces TEP, ils doivent s'efforcer de réaliser un produit fini (ampli audio), tuner, circuit à microprocesseurs, etc...).

C'est là une des 1ère forme de développement de l'esprit de créativité.

Une 2e particularité de cette école sans rapport en 1ère analyse, avec l'esprit de créativité est que 2 langues étrangères parlées
couramment sont nécessaires pour obtenir le diplôme. 8 h par semaine leur sont consacrées pendant 3 ans. Jointe à de sérieuses études en micro et macroéconomie, en droit international, ces études façonnent un profil "exportation" qui fait le renom de l'option de 3e année appelée "ingénieur d'affaires".

Mais les élèves qui pratiquent également 8 h de sport par semaine dans 22 clubs différents et trouvent ainsi leur équilibre, ont demandé que les laboratoires fondamentaux de l'école soient ouverts à leurs activités après les horaires de travail, le samedi et le dimanche.

C'est ainsi qu'ont été créés de nombreux clubs scientifiques, chacun d'eux étant pris en charge par un département technique. Nous avons vu aussi se créer :

le club d'électronique qui regroupe les fanatiques de la "bidouille". Il a à son actif, de nombreuses réalisations : amplis de toutes puissances, aux courbes de réponses impressionnantes, téléguidage de voitures, d'avions, d'engins, etc...

Le club radioamateur spécialisé dans la réception à vitesse lente d'images de télévision qui a déjà accroché partout dans le monde des correspondants nombreux.

Une branche de ce club a même réalisé comme application d'un TEP de 2e année, un poste émetteur de radio-diffusion de 50 Watts qui émet en stéréophonie sur la bande des 90 Mégahertz.

Ces 3 premiers clubs sont à la base d'une action assez spectaculaire et contestée qu'il est bon de conter ici.

Radio-Conquet, station d'émission réception chargée des communications radio-maritimes avec les flottilles de pêche bretonnes, a dû ces derniers mois changer son matériel et n'émet plus qu'en Bande Latérale Unique. Les familles des pêcheurs qui écoutaient ses émissions sur un poste récepteur classique, ne pouvaient donc plus le recevoir, et ainsi ils n'obtenaient plus d'informations sur les bateaux et leur équipage. Des protestations ont donc été faites par voie de journaux.

Le club électronique mis ainsi au courant de l'événement a proposé en 24 heures un montage simple de coût modique : 25 francs, permettant à tous les récepteurs de fonctionner en BLU.

Une réponse aussi rapide et aussi efficace n'est-elle pas une application de l'esprit de créativité.

D'autres clubs existent et leurs réalisations sont bien souvent conséquentes. Le club fusée a été primé hors concours au dernier salon du Bourget pour la réalisation de l'équipement nacelle d'un ballon sonde (mesure du taux d'ozone dans l'atmosphère). Ce même club participe à la réalisation du récepteur qui équipera le satellite radio-amateur ARSENE.

Ce sont donc là des réalisations presque industrielles qui constituent des applications immédiates aux cours professés.

Enfin, parmi les élèves s'est créé une "Junior Entreprise" appelée "Groupe de Recherche en Télécommunications" (GRT) dont le but est de réaliser pour toute société privée ou publique, des études théoriques ou pratiques pouvant aboutir à des produits finis. Cette "Junior Entreprise" qu'il faut considérer comme étant le prolongement des cours de l'école, rencontre les mêmes problèmes d'élaboration de 217
contrats, de financement, de réalisation dans un temps donné, de syndicats, qu'une PME et PMI.

Cette activité est donc formatrice. En outre, les problèmes qui sont posés n'ont pas en général de solution simple. Ce sont ceux sur lesquels de petits industriels ont buté par manque de connaissances dans un domaine donné.

A cette "Junior Entreprise" reviendra le mérite d'innover et de proposer des solutions originales sans lesquelles elle ne pourrait subsister.

La Direction ne fait qu'encourager ces initiatives mais aucune sélection autre que naturelle, n'a lieu pour trier les élèves et les affecter à tel ou tel club en fonction de leurs penchant, ou de leur capacité. Il suffit de donner à chacun d'eux les moyens de se réaliser en dehors de ses heures de travail (36 h de cours par semaine) et de suivre leurs efforts, de les aider un peu bien sûr (certains laboratoires ne peuvent être livrés aux élèves sans moniteur : la mécanique, la tôlerie, l'informatique, ce qui pose de sérieux problèmes d'encadrement). Le résultat vient tout seul.

Il est bien évident que de telles qualités chez la plupart de nos élèves ne s'épanouiraient pas si les enseignants ne les possédaient eux aussi au plus haut degré.

Dans cette école toute neuve où tout a été créé rapidement, au fil des semaines, puis revu et corrigé..., il a fallu que le corps professoral se donne sans compter pour parvenir aux buts fixés.

Dans chacun des départements, on a inventé en commun puis réalisé les montages pédagogiques, les cadres des travaux pratiques, les diverses phases des TEP.

L'étude des moyens nouveaux de télécommunications, de la télématique, de l'informatique, des microprocesseurs, se pratique au moyen de montages tous conçus et réalisés à l'école en fonction de la pédagogie adoptée.

Il en résulte une parfaite continuité de l'enseignement entre les cours magistraux (les moins nombreux possibles), les petites classes, les bureaux d'études, et les travaux pratiques.

En outre, certains montages, en avance sur les réalisations actuelles, rapportent finalement aux élèves les problèmes qui se posent par exemple, sur les connexions entre fibres optiques, la réalisation de fonction d'un autocommutateur.

Il vous faudrait pouvoir visiter cette école pour vous rendre compte de tout ce qui a été "créé" dans le but d'enseigner aux élèves les techniques de pointe qui rendront valables leur diplôme d'ingénieur pendant de longues années après leur sortie.

C'est ainsi qu'a été réalisé -je ne prendrai ceci que comme exemple- un autocommutateur temporel de toute petite taille : 50 cm x 40 x 20 avec lequel chaque étudiant peut suivre, expliquer, réaliser, les diverses fonctions correspondantes.

L'oeuvre est originale. Elle a été réalisée sous forme de 6 prototypes qui n'ont rien à envier à la technique de production industrielle. Il a fallu "innover" pour le concevoir, ce matériel n'existe pas dans le commerce, et pour le réaliser car il a été conçu à
partir des éléments les plus modernes de la technique.

Le potentiel de matière grise dont dispose cette école, la qualité
de son corps professoral, la complémentarité : ingénieurs en provenance
du Centre National d'Etudes des Télécommunications, ou de l'industrie,
docteurs d'état ayant aussi participé à des groupes de recherches, en
font un élément clé au plan national et régional.

Au plan national, il est ou sera associé à toutes les grandes en-
tités dans lesquelles s'effectue une recherche voire une "innovation"
de qualité.

Au plan régional il se propose de participer à des actions qui
regroupant les grandes écoles, les universités, les centres de
recherches existants, lui permettront de donner sa vraie mesure.

Appliquer ces études à résoudre des problèmes pluridisciplinaires,
leur rechercher des solutions adéquates et modernes n'est-ce pas aussi
"innover".

Cet esprit de "créativité" qui règne dans l'école n'est pas le seul
fait des scientifiques. Les 36 professeurs de langues qui enseignent
à l'école ont eux aussi à se mettre à la portée de ces élèves
difficiles pour lesquels, étant donné leurs caractéristiques psycho-
logiques et intellectuelles, aucune méthode d'apprentissage n'est
correcte.

Réaliser en 3 ans des enseignements aussi divers que l'anglais, le
russe, l'allemand, l'espagnol, le portugais et l'arabe, est un pro-
bème angoissant car le temps qui y est consacré n'est pas illimité:
dans chaque langue, des enseignants se sont groupés pour créer des
méthodes nouvelles d'apprentissage, basées sur la conversation, l'au-
dio-visuel (bandes sonores, magnétoscope, information du monde entier,
...)

Ces méthodes commencent à porter leurs fruits. Là aussi, notre
corps enseignant a "innové".

Il a pour le seconder un département audio-visuel bien équipé qui
sans cesse, crée des produits à haute valeur pédagogique, qui s'ins-
crivent en droite ligne des enseignements : diapositives, diaporamas,
film super 8, 16 m/m, vidéo pour télévision et magnétoscopes. Chacune
de ses activités résulte d'une souci constant de création dans un
ensemble où n'existe que peu de concurrence. Que ce soit pour
pénétrer dans le dédale de la technique, ou dans le complexe d'appren-
tissage d'une langue étrangère, notre production audio-visuelle est
avant tout créative.

Les élèves eux-mêmes y participent et créent lors d'un module
d'enseignement de 1ère année, approche des télécommunications, un
certain nombre de séquences dont chacune est la conclusion d'un
reportage et qu'ils réalisent entièrement, guidés dans la réalisation
technique mais laissés libres dans le déroulement du canevas.

Je n'insisterai pas sur la "créativité" de notre département EAO
(Enseignement Assisti par Ordinateur) qui "créé" en ce moment tant en
matières scientifiques et techniques qu'en langues, des logiciels et
des didacticiels permettant un large emploi de ce procédé dans tout
le cursus scolaire.

A-t-on ainsi répondu de façon précise aux attentes des élèves et
à ceux qui les emploieront à la sortie de l'école ? A-t-on pu leur donner cet esprit "d'innovation" qui leur permettra de se mieux placer sur le marché du travail, et surtout qui leur donnera la joie profonde d'avoir su "créer" et l'idée peut être ingénue et fausse que leur vie n'a pas été complètement inutile.

L'avenir le dira.
DIE VERMITTLUNG UNTERNEHMERISCHER QUALIFIKATIONEN IN DER AUS- UND WEITERBILDUNG DER INGENIEURE IN DER BUNDESREPUBLIK DEUTSCHLAND

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Siemens AG - München und Erlangen
BRD

ABSTRACT

Engineers are primarily engaged in responsible positions. The necessary managerial and entrepreneurial qualifications, - knowledge, skills, attitudes - are demonstrated. The education of an engineer can only include managerial knowledge to a limited extent due to the vast quantity of technical knowledge to be learnt. Nevertheless, important elements of managerial skills can be found in an engineer's formal education. Such elements are discussed so that they will receive increasingly more attention. Society and examples form managerial behaviour in an engineer's education and career. The necessary managerial knowledge is conveyed by further education.

RESUME

Les ingénieurs occupent essentiellement des postes de haute qualité. Les qualifications requises dans l'entreprise (savoir, capacité, comportement) sont mises en évidence. Leur formation ne peut donner aux ingénieurs que des rudiments de savoir au niveau de l'entreprise par suite de la masse de connaissances techniques. Elle contient néanmoins des éléments précieux d'information concernant l'entreprise. Ces éléments sont discutés afin de pouvoir être proposés dans une plus large mesure. La société et les modèles marquent le comportement au sein de l'entreprise dans la formation et la vie professionnelle. Le savoir nécessaire est assuré par une formation continue.

ZUSAMMENFASSUNG

1. EINFÜHRUNG

Der Wohlstand Westeuropas beruht ohne Zweifel zu einem großen Teil auf der Entwicklung, der Fertigung und dem weltweiten Vertrieb hochtechnischer Güter. Ingenieure und Naturwissenschaftler waren und sind am Erreichen und Erhalten dieses Zustandes maßgeblich beteiligt. In der Bundesrepublik Deutschland entfallen folgende Anteile der Universitätsabsolventen ausgewählter Studienfachrichtungen auf die Kategorien "Selbständig Tätige" (einschl. Unternehmer und Geschäftsführer) und "Angestellte":

<table>
<thead>
<tr>
<th>Fachrichtung</th>
<th>Selbständig Tätige</th>
<th>Angestellte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architektur</td>
<td>37 %</td>
<td>41 %</td>
</tr>
<tr>
<td>Bauingenieurwesen</td>
<td>17 %</td>
<td>53 %</td>
</tr>
<tr>
<td>Elektrotechnik</td>
<td>6 %</td>
<td>73 %</td>
</tr>
<tr>
<td>Maschinenbau</td>
<td>11 %</td>
<td>68 %</td>
</tr>
<tr>
<td>Wirtschaftsingenieurwesen</td>
<td>18 %</td>
<td>71 %</td>
</tr>
<tr>
<td>Physik</td>
<td>4 %</td>
<td>64 %</td>
</tr>
<tr>
<td>Chemie</td>
<td>6 %</td>
<td>75 %</td>
</tr>
</tbody>
</table>

Für Fachhochschulabsolventen gelten sehr ähnliche Verhältnisse. Zum Vergleich: In der Bundesrepublik Deutschland sind 8,6 % aller erwerbstätigen Personen selbständig tätig, 46 % aller Mediziner und 16 % aller Wirtschaftswissenschaftler. Der Anteil der selbständig oder als Unternehmer tätigen Ingenieure erscheint am Thema dieser Arbeit bewertet zunächst relativ gering, besonders für die Fachrichtung Elektrotechnik. In einem deutschen Großunternehmen der Elektroindustrie mit ca. 26.000 angestellten Ingenieuren und Naturwissenschaftlern, von denen ca. 60 % eine Ausbildung im Fach Elektrotechnik aufweisen, sind jedoch 7,8 % der Ingenieure und Naturwissenschaftler im Sinne des Gesetzes leitend tätig. Man muß aber noch die Schicht des verantwortlich tätigen mittleren Managements hinzurechnen. Sie umfaßt weitere 36,8 % der im Unternehmen beschäftigten Ingenieure und Naturwissenschaftler!

Ingenieure sind zwar in unterschiedlichen Funktionen und Positionen, jedoch nach einigen Berufsjahren in der Regel verantwortlich tätig. Sie benötigen neben profunden Fachkenntnissen unternehmerische Qualifikationen - nicht nur als Unternehmer, Manager oder selbständig Tätige, sondern auch als verantwortlich tätige Angestellte.

2. ÜBERBLICK ÜBER DIE NOTWENDIGEN UNTERNEHRERISCHEN QUALIFIKATIONEN

Unternehmerisches Handeln erfordert besondere Qualifikationen in den Bereichen des Wissens (knowledge), des Könnens (skills) und des Verhaltens (attitudes). Wesentliche unternehmerische Qualifikationen sind:

222
a. Wissen (Kenntnisse)

- Marktkenntnisse (Marktanalyse, -prognose)
- Kredit- und Finanzwesen
- Organisation
- Menschenführung
- Rechtskunde
- Methoden der Planung (auch Entcheidungsfindung), der Durchführung (Zusammenarbeit u. Handlungsabläufe), der Kontrolle
  von Vorhaben in allen ihren Phasen

b. Können (Fähigkeiten)

- logisches und analytisches Denken
- Ideenreichtum, Kreativität
- zielorientiertes Denken und Handeln
- Kritik- und Urteilsfähigkeit
- wirtschaftliches Denken, Kostendanken
- Verhandlungsfähigkeit, Überzeugungsfähigkeit
- praktische Erfahrungen

c. Verhalten (charakterliche Einstellungen)

- Leistungswille und Lernbereitschaft
- Kontaktfreudigkeit und Aufgeschlossenheit
- gesundes Selbstvertrauen, innere Sicherheit
- Initiative und Durchsetzungsvermögen
- Engagement und Ausdauer
- Pflichtbewußtsein und Verantwortungsbereitschaft
- Mut zum zukunftsorientierten Handeln bei geschäftlichem Risiko

3. DIE FÖRDERUNG UNTERNEHMERISCHER QUALIFIKATIONEN IN DER INGENIEUR­AUSBILDUNG

Unternehmerisches Wissen kann man in der Ingenieurausbildung explizit vermitteln, während Führungsfähigkeiten und charakterliche Einstellungen in der Regel nur indirekt gefördert werden können.

a. Die Vermittlung von unternehmerischem Wissen

In der klassischen (reinen) deutschen Ingenieurausbildung wird unternehmerisches Wissen nur in geringem Umfang angeboten. Wegen des umfangreichen und ständig wachsenden Fachwissens bleibt auch keine andere Wahl, denn fehlende fachliche Grundlagen können im späteren Berufsleben erfahrungsgemäß nur schwer oder kaum erworben werden. An den Münchener Ausbildungsstätten findet man die folgend aufgelisteten Lehrangebote.

Technische Universität:
- Fachrichtung Bauingenieurwesen: Pflichtvorlesung über Grundzü­


Fachhochschule:
- Fachrichtung Elektrotechnik: Pflichtvorlesung über Betriebswirtschaftslehre mit zwei Semesterwochenstunden.


In der Ausbildung zum Wirtschaftsingenieur wird unternehmerisches Wissen in wesentlich größerem Umfang vermittelt. An Universitäten und Fachhochschulen gibt es zwei Wege zum Wirtschaftsingenieur:
- Aufbaustudien im Anschluß an ein klassisches Studium einer Ingenieurwissenschaft, die in der Regel mindestens zwei Jahre zusätzlichen Studiums erfordern und die Gesamtstudienfahrt erheblich verlängern.

Wirtschaftsingenieure sind in relativ großem Umfang selbständig tätig (18 %). Im Angestelltenverhältnis tätige Wirtschaftsingenieure

b. Die Ausprägung unternehmerischen Könnens

ist über die Einflußfaktoren 1. Fachinhalte, 2. Unterrichtsmethoden und 3. Anwendung von Problemlösungsmethoden möglich. Hier einige ausgewählte Beispiele, die in Abschnitt 2b. erwähnte Qualifikationsmerkmale betreffen:

c. Die Beeinflussung charakterlicher Einstellungen

- Purtch vor der ungewissen Zukunft der Menschheit; Mangel an Zie-
len und Vorbildern,
- Furcht vor Überforderung durch hohe Innovationsgeschwindigkeit,
- mangelnde Motivation und wissenschaftliche Neugier, da die menschli-
  chen Grundbedürfnisse schon in jungen Jahren abgeseßtigt werden,
- kein Interesse an einer Karriere,
- Wunsch nach geregeltem Einkommen und Zufriedenheit.
Derartige Einstellungen können nur durch effektive und andauernde
Gegenwirkung geändert werden. Die Hochschule hat folgende Einfluss-
möglichkeiten:
- Das Vorbild des Hochschullehrers,
- die gezielte Bildung von Gruppen mit unternehmerischen Interessen,
  deren Individuen sich auch gegenseitig positiv beeinflussen.
Die Industrie kann dies durch die prägende Kraft geeigneter Berufs-
praktika unterstützen, für deren Inhalt hier Anhaltspunkte entnom-
men werden können.

4. DIE VERMITTLUNG UNTERNEHMERISCHER QUALIFIKATIONEN IN DER WEITER-
BILDUNG

Da in der Ingenieurausbildung unternehmerisches Wissen nur in be-
grenztem Umfang vermittelt und unternehmerisches Können sowie Ver-
halten im wesentlichen nur indirekt gefördert werden können, kommt
der Weiterbildung der Ingenieure auf dem Gebiet unternehmerischer
Qualifikationen besondere Bedeutung zu. Sie erfolgt

a. Am Arbeitsplatz (on the job)
- durch die Mitarbeit in geführten Projektgruppen,
- durch das unternehmerische Beispiel der Vorgesetzten,
- durch die schrittweise Übergabe von Verantwortung.
A. Jay (1968) stellte die Thesen auf: "Das einzig wirkliche Training
für einen Unternehmensführer ist Unternehmensführung" und "Der beste
Weg zu lernen, wie man große Unternehmen führt, ist es, kleine Un-
ternehmen zu führen". Aus der Sicht der Großunternehmen kann man an-
stelle der Führung kleiner Unternehmen auch die Führung von Teilein-
heiten großer Unternehmen empfehlen. Künftige Unternehmer oder Mana-
ger benötigen natürlich Mut zum unternehmerischen Risiko. Diesen Mut
benötigen jedoch auch die Unternehmensführungen, damit sie junge ta-

tenierte Ingenieure nicht zulange warten lassen, ehe sie ihnen Ver-
antwortung übertragen.

b. In der betrieblichen Führungskräfteenschulung

Große Unternehmen halten in der Regel aufeinander aufbauende Se-
minare ab, in die durch das betriebliche Beurteilungswesen als för-
derungswürdig erkannte Mitarbeiter während ihrer Karriere zu den
passenden Zeitpunkten entsandt werden. Ein Seminar dauert maximal
c. vier Wochen. Nacheinander wird Wissen über Menschenführung und
Gruppenverhalten, betriebswirtschaftliches Wissen und schließlich
Wissen über größere unternehmerische, gesamtwirtschaftliche und ge-

c. In der außerbetrieblichen Führungskräfte schulung

Die unter 4b. genannten Themen werden auch von zahlreichen privaten und öffentlichen Bildungseinrichtungen angeboten. Besonders kleine und mittlere Unternehmen entsenden ihre künftigen Führungskräfte dorthin. Große Unternehmen entsenden besonders qualifizierte Führungsnachwuchskräfte auch zu länger dauernden Bildungsmaßnahmen, wie sie beispielsweise vom Universitätsseminar der Wirtschaft (USW) in Deutschland, INSEAD in Frankreich oder der Harvard University, Graduate School of Business Administration, in den USA angeboten werden.

Die Industrie- und Handelskammern sowie die Volkshochschulen bieten auch Seminare zum Thema "Ich mache mich selbständig - Informationen und Entscheidungshilfen zur Betriebsgründung" an.

5. SCHLUSS


QUELLEN

Theme 4. Academic-Industrial Liaison

a. Academic-Industrial interaction and contacts
b. Academic-Industrial collaboration
c. Training projects for students in industry
d. Channels of exchange of technology
e. Communicating with a lay public
f. Governmental innovation policy and incentives

Chairmen: D. Seitzer and D. Golling (BRD)
Rapporteurs: P. Thust (BRD) and J. Jaen (Spain)
Alpha Displays Limited (ADL) is a fictitious company providing a setting for a system of linked situations, all modelled on actual events and actions in several similar real enterprises. ADL may therefore be considered as a Learning Company formed from a tenable amalgan of actual companies. The situations are set up and course members adopt specified roles within them. Some of the situations are of especial value in enhancing both innovation and entrepreneur­ship, for example through students:
- compiling a report on establishing an R & D unit
- making decisions on their own product proposals
- planning the expansion of an embryonic ADL
1. THE LEARNING COMPANY CONCEPT

Alpha Displays Limited (ADL) is a fictitious company which provides the background to a system of situations, each of which is modelled on actual events and actions which have taken place in one or another of several similar real enterprises. ADL can therefore be considered as a tenable amalgam of companies. Where appropriate, when adapting actual situations to the ADL setting, distortions of reality have been introduced to provide greater learning opportunities. For this and other reasons ADL can be regarded as a specially created Learning Company. Although the individual teaching methods used are well-known, the overall concept of the Learning Company appears to be new and to represent a radical departure from the case study and business game approaches.

A series of linked situations are set up, each emphasising "what is" rather than "what should be". The students adopt various roles within the situations which, subject to certain curriculum restraints, are then "free running" and consequently "rich" in outcomes. As many aspects as possible of each situation, as it develops through the influence of participants, are evaluated - for example process as well as content, unpredicted as well as predicted.

Learning is not confined to students. Tutors can apply concepts and techniques to a simulated situation in the same manner as to an actual situation. In this regard it is important to resist modifying a learning situation to enable standard teaching material to be used.

2. ALPHA DISPLAYS LIMITED

In imagination, the present-day ADL has grown from Turgon Electronics Limited, which was founded in the U.K. over ten years ago by two entrepreneurs, one an engineer and the other a semi-retired financier. The company started operations from a back-garden shed and after overcoming some initial setbacks grew steadily. Turgon's products were all based on the cathode ray tube and served the industrial, commercial and educational markets. The company moved to a new factory but then disaster struck - the founding engineer died as a result of an accident. His partner sold Turgon Electronics to The
Alpha Group which was seeking to diversify from its main field of packaging machinery.

The new owners recruited senior managers to run the company and changed its name to Alpha Displays Limited. For a while the company prospered, its new products being production engineered from prototypes "bequeathed" by the founding engineer. Then, faced with decreasing growth and profitability, ADL's managing director established a research and development department and recruited an R and D manager to run it. He also made structural changes in the organisation and established a committee with associated procedures to select new products and control their evolution within the company.

Alpha Displays Limited is thus now a £3 million turnover company developing, batch-producing and marketing electronic equipment to industrial and other non-domestic users. It is part of a group of companies and obtains a substantial proportion of its turnover from export sales.

The characteristics and history of ADL were originally formulated to provide a vehicle for imparting a general management overview of the research and development function and of the evolution of products within the company. Although ADL now serves a much wider purpose, its origin makes it of particular value in enhancing innovation and entrepreneurship by engineers.

3. THE ADL EXERCISE

The present ADL exercise comprises 8 sequential Stages. In every Stage, students are required to carry out one or more tasks. The tasks provide opportunities to apply knowledge, skills and understanding obtained from lectures in other subjects, from input sessions which immediately precede a particular Stage and from experience. Each task is carried out in the context of a specified situation into which the students are placed. In addition to the 8 Stages there are 4 Episodes which are optional, i.e. they can be used or omitted without affecting the main sequence.

As in real life, students proceeding through the exercise build up a knowledge of ADL and come to understand its ramifications gradually and not necessarily chronologically. As they proceed through the 8 Stages their roles change from individual external commentators, through membership of the ADL management team, to acting as ADL functional managers. A diversity of learning methods are employed including syndicate tasks, in-tray simulation, CCTV evaluation and role-playing.

The response of participants to each situation is usually evaluated on a multi-disciplinary basis. The systems nature of the exercise enables progressive development of a particular field of study to take place - for example group processes are examined in general terms in an early Stage and in greater depth as the exercise proceeds.

The "porous" nature of the ADL situations (i.e. neither open-
ended nor closed system), the emphasis on process as well as content and the featuring of communication and behaviour are of particular value in developing the attributes dissimilar to those required for "hard" engineering (Beck H.V., 1981), on which innovation and entrepreneurship appear to depend.

4. AN ADL EXERCISE FOR ENGINEERING STUDENTS

The ADL exercise has been used in various forms in postgraduate degree and diploma courses in science, engineering and management subjects, in short courses for particular companies and in an undergraduate course in business studies. A short ADL exercise for engineering undergraduates has also been developed over three intakes of a CNAA BSc degree course in industrial engineering. It was last provided in the Autumn 1981 term to a 4th-year class of 20 students and it is this version which will be described.

The exercise took place over seven weeks with one 3-hour session each week. Individual coursework was required between sessions amounting to about another 3 hours. A typical session was structured as follows:

| ¼ hour | Presentations | 3 of 4 minutes, process assessed |
| ¼ hour | Stage Task | Group work |
| ¼ hour | Stage Evaluation | Content and/or process |
| ¼ hour | Individual Work | Feedback of assessment |
| ¼ hour | Briefing | Work for next session |

The objectives to be met by the exercise were:

a. to impart an understanding of the concept of self-management
b. to develop personal resources such as abilities to communicate, work in a team and make effective use of time
c. to enhance dissimilar attributes such as coping with uncertainty, understanding people and making decisions
d. to provide an opportunity to apply knowledge, understanding and skills to problem solving and other activities
e. to create awareness of the processes associated with the evolution of products, with especial reference to product policy and R&D
f. to foster on a "what is" rather than "what should be" basis an understanding of structures and relationships within a company and of the managerial environment in which engineering activities take place

Although the attainment of each of these objectives could contribute to the enhancement of product and business creativity, those of most direct relevance are e with regard to innovation and f in relation to entrepreneurship. The Stages and Episodes of the ADL
exercise which meet these objectives and the organisation of the work and sessions in which they are used will now be described.

5. ADL STAGES 3 and 4

In Stage 3, the course was divided into three groups and the situation was established in which each group played the role of a firm of consultants advising ADL's managing director on setting up an R & D unit and proposing a scheme for managerial control of the evolution of new products. The managing director had provided some additional background information on ADL and gave a series of headings covering the topics in which he was interested. The Stage 3 Task was to produce in about 2½ hours a written report in response to the managing director's brief.

The Stage 3 paper specifying the situation and task was given out at the end of the previous session so that the groups could prepare. At the same time three students were selected, one from each group, to make 4-minute presentations. Their situation was defined as that of a member of a firm of consultants making a presentation to colleagues explaining what ADL has asked the firm to do.

Shortly after the start of the session the three presentations were made in sequence to the whole course. Although only the process of presentation was assessed, the content was of value to all of the groups in setting the scene for the task ahead and also ensuring that at least one member of each group had made some detailed preparation! After the presentations the three groups carried out the Stage 3 Task and the written reports were received at the end of the session.

Students were then informed of the Stage 4 Task - they were to act as teams of ADL managers of unspecified functions, placing in order of preference the reports received from the firm of consultants. For this purpose new groups were announced consisting of a mixture of members of the Stage 3 groups, to dilute loyalty to any one report. Also, another three students, again one from each of the new groups, were briefed to make 4-minute presentations to a prescribed audience on the methods which could be used to evaluate the reports.

The handwritten reports were typed and reproduced for distribution at the start of the next session together with a report from a fourth firm of consultants (Syndicate j) which was to be evaluated on the same basis as the students' contributions. After the presentations, the Stage 4 Task was carried out, followed by verbal reporting to a plenary session by each of the groups. In each case the Syndicate j report came out of top, though it was deliberately not made a definitive "answer" but aimed instead at identifying major issues. The discussion on these and on the methods and reasons for placing the students' reports in a particular order provided much material for learning about the departmental and managerial environment of product innovation.
6. ADL STAGE 7 AND E3 COURSEWORK

In the Syndicate j report it is recommended that a New Products committee be set up. The report also includes a sample form on which proposals for new products should be made.

In Stage 7 each student was asked to submit a product proposal and also carry out individual coursework E3 which required the formulation of a product policy for ADL.

In the appropriate session, after E3 presentations by another three students, one statement of ADL's product policy was adopted. The course was then divided into groups which short-listed the students' proposals, together with one from "outside", using the agreed policy as a criterion. At a plenary session, a composite short-list was drawn up and adopted by all three groups.

The roles of managing director, marketing manager, R & D manager, works manager, company chief accountant and others were assigned to individual students within each group, which in effect became New Products committees. Stage 7 Task 1 was then carried out. In this, all of the managing directors and company chief accountants met together to plan the first meeting of the committee and to draw up an agreed agenda. In the meantime the marketing managers agreed a marketing view on each product proposal and similarly with the R & D managers and the works managers. In private, the managing directors were requested to ensure that the "outside" proposal was accepted by the committee whatever the comments of their managers because the Chairman's wife (or some such) had expressed an interest. On completion of Task 1 the short-listed product proposals were typed up in full so that the comments of the three functional managers were brought together for the first time and these, along with the agenda, were reproduced for each student.

At the next session, a further three presentations were made on the purposes of the New Products committee and the possible contribution of the presenter (in his committee role) to its deliberation. This was followed by a brief period of final preparation for the committee meeting during which the marketing managers were given a letter from a USA company regarding a manufacturing licence, to deal with as they thought fit. The three parallel committee meetings then took place, lasting about one hour, during which a decision was made on each proposal. The meetings were subsequently evaluated in a plenary session both from the process and the content points of view.

By participating in decision-making on their own and "external" proposals using a qualitative basis which covered the requirements of the market, the internal functions of the company and "political" aspects, students became aware of some major aspects of the context required for innovation to be successful.
7. El COURSEWORK

Shortly after the start of the exercise students were required to carry out El, an individual piece of coursework concerned with the genesis of the company. The first eighteen months of Turgon Electronics were described and the students placed in the position of the two entrepreneurs making plans for growth. Among the issues examined were organisation structure, including making provision for both batch and one-off production, and quantification as a guide to planning. The exercise provided a number of insights into how enterprises actually emerge. This was reinforced by an extra session in which the proprietor of a small business described how he had established a company manufacturing plastic bottles and what his attitudes were to making money, how it affected his family and other personal issues.

8. EXERCISE EVALUATION

By questionnaires provided during and at the end of the exercise detailed student feedback was obtained. The response was enthusiastic. 19 of the 20 students thought that the exercise should be provided in future courses and it was gratifying that only 1 piece of coursework was not submitted, out of a total of 100. The insights into the introduction of new products and the way in which a company runs were much appreciated as were the process, behavioural and decision-making aspects. Among other comments made by students were:

- learning was very subtle although effective
- it is an alternative way of learning that makes it interesting
- a most practical series of sessions and thoroughly enjoyable
- it emphasised punctuality, time discipline and working with colleagues (rather than friends) which will be useful for work
- more engineering problems should be added to it i.e. design problems

Probably all of the outcomes of the ADL exercise are of some value in enhancing innovation and entrepreneurship. The Learning Company method enables such outcomes to be obtained in an acceptable, realistic and topical manner.

TEN YEARS OF EXPERIENCE IN ACADEMIC INDUSTRIAL CONTACTS - THE RISKS

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ABSTRACT

During the last ten years the author has been involved, from the University, in establishing industrial contacts in order to support technological research in the field of Biomedical Instrumentation. From this experience some conclusions can be drawn. The most important may be the need for a solid infrastructural support from the University so as to assure the continuity of these activities. This means administrative flexibility in the use of the funds, both for personnel and material expenses. Legal support and the creation of a favourable environment for these activities are also important contributions for the maintenance of the final goals, both scientific and social. The main risk for the University, if these needs are not fulfilled, is that the researchers will finally try to find their way out from the institution in order to obtain a greater freedom from the bureaucratic constraints and a bigger economic profit from their efforts.

RESUME

Pendant les dernières années l'auteur s'est mis, à partir de l'Université, à établir des contacts avec l'industrie avec la finalité de supporter la recherche technologique dans le domaine de l'Instrumentation Biomedicale. On peut attirer quelques conclusions de cette expérience. Peut-être la plus importante c'est que l'Université donne un support infrastructurel solide que assure la continuité de ces activités. Ça veut dire l'existence d'une flexibilité administrative pour l'emploi des provisions économiques tant pour les conts matériels qu'en personnel. Le support legal et la création d'un environnement favorable pour ces activités contribuent d'une façon importante à acquérir les buts finals aussi dans le domain scientifique que dans le social. Dans le cas où ces nécessites ne soient pas atteintes, l'Université risque que leurs chercheurs aillent dehors pour échapper les constrainedes burocratiques et pour obtenir un meilleur profit économique à leurs efforts.
1. THE BASICS

During the last ten years the author has been the Head of a Biomedical Engineering Department in Electronics and Telecommunications Engineering School. This Department has been heavily involved in research and development activities with the Spanish industry, so that at present we can say that a big proportion of biomedical equipment now being manufactured in Spain with local technology has, somehow, had something to do with our department. In a certain moment more than 17 full time engineers have been working in research and development tasks in the department of which only roughly, one third were being paid by the University. The funding for the rest came from industrial contracts.

We feel that the collective and personal experience gained during these years can be valuable for new groups engaging on research and development activities at any Technical University. Moreover, we also feel that the problems that we have encountered are somehow similar from those of other places in Europe in a certain contrast with how things work on the other side of the Atlantic.

We have summarized our experience in a few axioms. This means that their fulfilment is a necessary but not sufficient condition for success in the academic-industrial relations. The statement of each axiom will be followed by corollaries and further comments.

2. ACADEMIC INDUSTRIAL RELATION IS IMPORTANT BUSINESS

This statement is not obvious in any environment, but it is specially true for the academical institutions. The industry can get through without the aid of the University, but the opposite is noxious for the academics and for the University as a whole. There is a certain lack of interest or even a certain prevention in some crowds of teachers against this co-operation, probably due to some of the following reasons: a) Teachers may be afraid of going into a certain contest with the industrial technical staffs due to the lack of competence in practical issues, b) Teachers may argue that industrial development is not something worthwhile for scientists, c) Students may argue that if the University works in industrial projects it may affect the attention paid by the teaching staff to their problems, d) Some conceptual political problems may arise in public Universities concerning the aid given to private industries making use of the money raised through the taxes, e) It is easier for a teacher to just dedicate itself to strictly academic business instead of bothering with other outside problems.

None of the previous reasons has enough weight in the author's view in front of the dangers that can be encountered if no industrial-academic work is carried out. The academic staff cannot risk becoming fossilized, specially in engineering education in an era where things change so rapidly due to the advancement of Technology. Those that are not able to contribute somehow to the sign of the
times cannot transmit in optimum conditions this assumed knowledge.
It is obvious that the University cannot work as a manufacture going
into a contest with others, because it is not its duty, however,
contributing with new ideas, prototyping and assessment of different
technological issues is something feasible and desirable if the aca-
demic staff wants to keep pace with the technological national effort.

3. TOO MUCH DEPENDENCE ON INDUSTRY IS NOT A GOOD BUSINESS

This statement is the counterpart of the previous one. If the
efforts of the University are too biased towards research and devel-
opment for the industry, it is obvious, that the purely academic set
up will be affected. The laboratories will be designed with a certain
lack for teaching possibilities. Thus, critical and expensive equip­
ment may not be suitable for routine use by the students. On the
other hand, constraints of the academic institution, too much de­
pendence from industrial funding may lead to a never ending race for
signing new co-operation contracts if the institution wants to main­
tain its material and human means in good condition. Public Univer­
sities must rely mainly on public funding in order to assure a cer­
tain stability of the system. We feel that industrial funding must
be maintained not above 30% of the institution's budget.

4. R+D MUST BE PAID FOR

The industry cannot think that doing research and development
in the University is worthwhile because it may be cheap. It must
rely on technical competence and in the suitability of the type of
project to be carried out by the University. The industry must pay
for the real profit it makes with the projects developed by academ­
ical institutions. The problem is not 'let's help these nice guys
for what they have done'. The relationship must be established
strictly on professional terms. It may be obvious that the University
can be cheaper than other private institutions in R+D activities be­
cause of the previous existence of a certain material and human in­
frastucture that must not necessarily be funded by the industry,
but the latter must be aware they must pay for the use of public
facilities. Difficulties might arise if concepts are not clear in
this respect. Both the industry and the University can be lead to a
situation of lack of interest towards R+D activities if they are not
valoured in their suitable terms.

5. ACADEMIC STAFF MUST BEHAVE PROFESSIONALLY

If the relationship between the industry and the academical in­
stitutions is to be taken seriously from both parts, the academic
staff must avoid certain types of attitudes frequently encountered
at the University. Things must be done in due time, they cannot hold on forever. Difficulties can arise in any R+D activity, but efforts must be made in order to give them an appropriate solution without too much delay. This assertion holds specially true in relation with the existence of quite a lot of academic holidays. The industrial technological problems must be given a valid solution in the normal industrial time scale if the University is to be considered professional in this respect.

6. NEED OF A CRITICAL MASS IN THE UNIVERSITY

Nowadays it is unbelievable to do important R+D activities in this field they must be carried out by homogeneous groups of professional, well trained, experts in the different technological fields. If a University department does not have a minimum amount of material means and people it is useless to face a certain level project with a minimum possibility of success. This means that if in an institution departments are small, some kind of interdepartmental agreements must be established before these kinds of activities are taken into consideration. The academical institution must also cooperate in this effort providing a minimum of common technical infrastructure to help in the development of these activities. In the case of electronic engineering this can be translated in the need for some mechanical support, common services for printed circuit design and development, bibliographic retrieval facilities, measurement equipment calibration and maintenance service, etc.

7. R+D WORK MUST BE REWARDING FOR THE ACADEMICS

It is often said that higher education must be something vocational. However as the social and institutional roles evolve with an ever changing environment, academical institutions must keep pace with these changes. Research at the University must be rewarding for the researchers if some kind of stability of the system is to be attained. These rewards must be both material and immaterial. This means that the real salaries of academical researchers must be in accordance with their industrial counterparts. University salaries have always been lower than those of the industry and this can be accepted by the academics up to a certain point if they have some other kinds of compensations. Anyway, a situation where the difference is too high unavoidably leads to a leak of the best individuals towards the industry once they attain a certain technical competence and a certain age. It is easy to maintain a young postgraduate with a low salary for a period during which he becomes a full professional by gaining experience. However, temptations from the industry might become too strong after three or four years of being engaged in R+D projects at the University. The only way to avoid this effect is to stimulate and compensate the efforts developed by the technic-
ally competent individual by gradually paying him adequately. On the other hand some kind of advantages can compensate the differences in wages. Easiness in attending congresses, establishing contacts with foreign colleagues and some kind of internal and social recognition of the researcher's work can compensate him from a lower wage. The academical institution can play here a vital role in diffusing R+D activities in the social media in order to attain this recognition. At the same time a certain internal credit must be given for good 'performers' facilitating promotions within the academical levels.

8. ADMINISTRATIVE FRAMEWORK IS ESSENTIAL

The academical institution must provide a favourable administrative framework for the R+D activities in connection with the industry if it wants to develop and get some profit from there. Both from the organization and economical points of view, R+D activities must be left to the departments, which are the real agents of them. Funds must be flexibly administrated without too much bureaucracy. Often, time plays a vital role in obtaining some devices and pieces of equipment if a certain development is to succeed. The University must control the funding but letting the responsibility of the expenditures to the people in close contact with the problems if they are to have any responsibility in the results of their work. If this condition is not fulfilled it might lead to 'tricky' situations where the departments have a tendency to behave as small, somewhat illegal enterprises within the institution in an effort to avoid bureaucratic constraints and finally giving rise to disillusionment. It is not the first time that an homogeneous group of scientists has preferred to separate from the University and create their own technological enterprise in view of the strict bureaucratic constraints imposed by the academical institution. The main point here is that the University as a whole must have a clear policy trying to favour an academical industrial relationship. If imagination is absent from the leaders of the University it will soon be changed by bureaucratic controls leading to languishing R+D activities.

9. CONCLUSIONS

We feel that academic industrial collaboration is not only desirable but extremely important for a lively transmission of knowledge within the University. However, this statement does not seem to be obvious everywhere, leading to some kind of verbalism that is not followed by action. The engineering educators that are convinced of the previous statement must play a militant role in the promotion of these activities in front of both the University and the industry.
PRAXISSEMESTER ALS WECHSELSITIGER TECHNOLOGIETRANSFER ZWISCHEN HOCHSCHULE UND INDUSTRIE

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ABSTRACT

Practical semesters for the students and teaching staff of technical colleges call for positive interaction and good relations between technical colleges and industry. Such semesters lead to the development and improvement of engineering students' innovative and entrepreneurial skills.

The article presents an account of experience gained as to the types of practice-oriented work that may usefully be carried out in such semesters. Particular attention is given to the example of the modernization of the Rourkela broad strip rolling mill, i.e. the technology transfer from technical education to practical engineering activities, and vice versa. Practical semesters for technical college lecturers are an important means of introducing professional engineering experience into technical college teaching of the subjects concerned.

RESUME

Les semestres de stage pour étudiants et professeurs de l'enseignement supérieur sont générateurs d'interactions intenses et de contacts étroits entre les établissements d'enseignement supérieur et l'industrie. Ils contribuent au développement et à l'amélioration de la formation des ingénieurs, en visant la promotion de leurs facultés de créatifs et d'entrepreneurs.

L'exposé rapporte l'expérience acquise dans le domaine des semestres de stage et met en évidence les avantages des affectations dans des conditions de travail réelles. Sur l'exemple de la modernisation du laminoir à larges bandes Rourkela, on illustre le transfert technologique entre l'enseignement et les activités d'ingénieur dans la réalité, et vice versa, entre les activités pratiques dans l'industrie et l'enseignement. Pour les professeurs, les semestres de stage constituent une composante pédagogique importante, leur permettant d'intégrer dans l'enseignement de leur spécialité les fruits de l'expérience acquise dans la pratique professionnelle.
1. TECHNOLOGIETRANSFER IN PRAXISSEMESTERN


Gegenstand dieser Tätigkeit kann sein:

- Die Mitwirkung an der Lösung von Problemen des Faches in der Praxis.
- Die Umsetzung theoretischer Modelle in die Praxis.
- Unter Eingliederung in den Arbeitsprozess die Wahrnehmung von Aufgaben, die in ihren Anforderungen der Qualifikation des Antragstellers entsprechen.


2. MODERNISIERUNG DES BREITBANDWALZWERKES ROURKELA


Von der Fertigstaffel wurde eine sowohl mechanisch wie elektrisch neue fliegende Schere aufgebaut. Der digitale Teil der Scherensteuerung und -regelung besteht aus dem Schaltkreissystem Simatic-C3.

Die Bandkühlung hinter der Fertigstaffel für die elektrisch eine Bandverfolgung und eine Auswahl zwischen vorprogrammierten Spritzmustern vorgesehen ist, wurde ebenfalls erneuert. Für die Auslaufrollgänge und Haspeln wurde ebenfalls eine neue Regelung und überlagerte Steuerung projektiert. Die Regelungen für Haspeldorn, Andrückrollen und Treiber wurden überarbeitet.

3. PRAXISBEZUG DER FACHHOCHSCHULSTUDIENGÄNGE


A NATIONAL PROGRAMME IN EDUCATION FOR INNOVATION -
THE IRISH EXPERIENCE

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ABSTRACT

This paper describes a programme undertaken by a National Working
Party of University Deans and co-ordinated by the National Board
for Science and Technology. The aims of the programme are to make
recommendations and seek implementation of steps to involve the
educational sector more closely with industrial innovation and
support services. Information is presented on how the programme
was organised nationally and some of the issues identified.

RESUME

Ce document décrit un programme entrepris par une équipe nationale
de doyens d'université en coordination avec une Commission
Nationale pour la Science et la Technologie. Les buts du
programme sont de faire des recommandations et de rechercher la
mise en œuvre de démarches engageant le secteur de l'enseignement
plus étroitement avec le changement industriel et les services
d'appui. On nous informe sur la façon dont le programme a été
organisé à l'échelle nationale et sur certaines des questions
identifiées.

ZUSAMMENFASSUNG

Dieses Papier beschreibt ein Programm, das von einer nationalen,
aus Universitätsdekanen bestehenden Arbeitsgruppe durchgeführt
und vom Nationalausschuss für Wissenschaft und Technik koordin-
iert wurde. Die Ziele des Programms sind, Empfehlungen vorzul-
egen und die Durchführung von Schritten anzustreben, die den
Bildungssektor näher an industriellen Neuerungen und flankierenden
Diensten beteiligen. Das Papier informiert darüber, wie das
Programm auf nationaler Ebene organisiert wurde, sowie darüber,
welche Probleme identifiziert wurden.

BACKGROUND

Irish industrial policy in the last two decades has been geared
to cope with a significant shift from a largely agricultural to an urban society and a rapidly growing population and workforce. The strategy adopted has been to concentrate on direct investment by foreign companies. The objectives of this approach included creating the maximum level of employment and establishing a modern industrial base in the country. This strategy was successful in attracting high technology industry in the engineering, electronics and chemical industries. However, this did not lead to strong linkages between indigenous and foreign owned firms and the level of indigenous high technology entrepreneurship was less than optimum. The need has been apparent for some time to build up indigenous technology resulting in Irish firms capable of trading internationally in high value added products. The strategy now under debate is to assimilate selected foreign technology in conjunction with the development of indigenous technological capability.

To date there has been no integrated national policy on innovation as a specific policy area as distinct from initiatives to stimulate small industry and generate indigenous enterprise. However, the Enterprise Development Programme within the Industrial Development Authority (IDA) is increasing in importance and another state agency the Shannon Free Airport Development Company (SFADCO) is developing small industry and encouraging entrepreneurship in the South-West region of the country.

Some initiatives in the area of innovation which have been taken in recent years include:

- The setting up of the National Board for Science and Technology in 1978 to advise Government on science and technology for economic development and to promote science and technology through its own programmes and funding mechanisms.
- The establishment of two "technological universities" the National Institute for Higher Education (NIHE) at Limerick and Dublin.
- The expansion of engineering output over the last two years so as to double it by the end of this decade.
- The establishment of the Innovation Centre for small industry on the NIHE Limerick campus.
- The setting up of a Microelectronics Applications Centre also on the same campus.
- The establishment of the European Research Institute of Ireland (The European Associate of the Georgia Institute of Technology).
The National Board for Science and Technology has contributed to the review of industrial strategy mentioned previously and is developing concepts for national policy on technological innovation. It is also in close contact with the educational sector and seeks to influence its development to meet national needs. In examining innovation policy the need for an initiative, in relation to Education for Innovation and Entrepreneurship was perceived. As part of this ongoing mission the Board established in early 1981 a programme entitled Education for Innovation and Entrepreneurship to coordinate and facilitate university Deans in exploring new roles for their institutes in the areas of innovation and entrepreneurship.

AIM

The project aims were: to provide a valuable forum for educational interests to come together and achieve a national focus on this topic; to make recommendations which will enhance the ability of our highly trained manpower to become more innovative; to make recommendations and seek implementation of steps to involve the higher educational sector more closely with industrial innovation and support services.

METHODS

The programme consisted of 3 phases as follows:

Phase 1: Establishment of National Working Party and Working Groups;

Phase 2: Substantive Work Phase:
- data collection and report writing;

Phase 3: Synthesis, Conference and Reporting:
- synthesis of reports
- national conference
- drafting recommendations
- dissemination of conclusions and recommendations

In late 1980 a decision to set up a National Working Party of Deans was taken. This involved 8 higher educational institutes and had representation from Faculties of Science, Engineering and Commerce. The groups also set up five associated Working Groups in the following areas:

1. Teaching and learning systems;
2. Research;
3. Higher Education/Industry Interaction;
4. Policy Issues
5. Entrepreneurship and Society;
The members of the five working groups engaged in activities as follows:

- data collection
- attendance at conferences such as SEFI 1981 and presentation of papers
- industrial visits
- preparation of discussion papers on various aspects of the topic

The activities culminated in reports from the Working Groups which were presented in November 1981.

Planning then began for the National Conference on Education for Innovation and Entrepreneurship to be held at the end of March. The Conference encompasses many of the themes in this present SEFI Conference and involves interaction between industrialists and academics in order to focus more clearly on what each group requires of the other and what the important issues are.

The reports from the Working Groups were synthesised into a single document and this formed the central element for discussion at the Conference. Some of the policy issues identified include:

- the stimulation of creativity and appropriate course modules for making students of Engineering Science and Commerce more aware of innovation.
- The barriers within the higher educational system to co-operation with industry and policies to remove them.
- The role of Innovation Centres in teaching and interaction with industry.
- The stimulation of entrepreneurship within society through government action.

RESULTS

- Following the conference a small group drawn from the National Working Party of Deans and the NBST drafted recommendations for action by Government and the educational sector.
- The educational sector has been informed of the issues and this will encourage Deans and other academics to involve themselves in devising appropriate strategies and in pressing for the necessary changes within their institutes.
A selection of industrialists attending the conference have been informed of the issues and this may make them more open to cooperating with the educational sector.

DISCUSSION

It is not possible to evaluate the success of the programme at this stage. However some general observations may be made. The idea of involving a broad and nationally representative group of University Deans in calling for a re-examination of education's role in relation to industry is regarded as innovative in itself. It was possible through this method to reach and involve a wide range of academics and university administrators and the National Working Party of Deans provides a national framework for discussion and lobbying on these issues.
A NON TRADITIONAL INTERPRETATION OF THE ROLES OF ENTREPRENEURSHIP IN LESS DEVELOPED COUNTRIES AND ITS IMPLICATIONS FOR THE ENGINEERING EDUCATION

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Turkey

ABSTRACT

This paper first summarizes the traditional Western views of the role of the entrepreneurs in economic growth. Then it concentrates on the entrepreneurship in the contemporary less developed countries (LDC) in terms of the entrepreneurial roles in transfer, adoption, and adaptation of technology relative to the requirements of these economies and concludes that the entrepreneur is usually the primary source of innovations in the individual firm in LDCs. Finally the paper points out the implications of the process of developing entrepreneurial technological competence for the education programs of engineering schools of the LDCs. Interviews conducted within the framework of a broader study of the introduction and dissemination of technology information in various industries in Southern Turkey are used as the primary source of data.

RESUME

Dans un premier temps, ce travail résume les vues traditionnelles de l'Occident sur le rôle joué par les entrepreneurs dans la croissance économique. Ensuite, il se concentre sur l'entrepreneurship dans les pays contemporains moins développés en des termes des fonctions de l'entrepreneur pour ce qui est de transférer, l'adoption et l'adaptation de la technologie relative aux besoins de ces économies et conclue que l'entrepreneur est souvent la première source des innovations dans la firme individuelle dans les pays moins développés. Finalement, on attire l'attention sur les implications du processus du développement des compétences technologiques entrepreneuriales pour les programmes de l'éducation des écoles d'ingénierie dans les pays moins développés. Les interviews conduites dans le cadre d'une étude élargie de l'introduction et dissémination de l'information sur la technologie dans les industries diverses au Sud-est de la Turquie sont utilisées en tant que source primaire de data.

Since the second world war the developing countries of today have been experiencing a transition period, from agrarianism into modern industrial growth. The most crucial issue faced during this transition period has been the acquisition of a 'technological capacity',
i.e. the capacity for the generation and dissemination of technological information on the production process (innovations). Since the central issue in developing economies is the acquisition of the 'technological capacity', not the 'efficiency' and 'instability' of the industrially advanced countries, the role of the entrepreneur for the contemporary LDC must be assessed in a different and new light.

1. THE TRADITIONAL VIEW OF THE ROLE OF THE ENTREPRENEUR

The classical economists considered the entrepreneur essentially in relation to risk and profit. The entrepreneur borrows capital, rents land, and hires labour against payments of fixed interest, rent, and wages; he receives a profit in compensation for his risk and efforts only if the enterprise is successful. John Stuart Mill thought that profit represents indemnity for risk and remuneration for the labour and skill required to supervise the enterprise. Risk-taking and management were thus in his view, the essential functions of the entrepreneur. This traditional view of the role of the entrepreneur as advanced by the industrially developed countries of the West emphasizing his risk-taking and managerial functions has not basically changed. The only exception was the Schumpeterian view which stressed that the primary importance of the entrepreneur lies in his introduction of innovations and which was directed mainly at the search for an explanation of economic instability.

This limited interpretation of the role of the entrepreneur in developed countries is based on the fact that in these countries there exists a supply of economic agents (skilled labourers and entrepreneurs as well as technically competent engineers, scientists, lawyers, accountants, etc.) and a well-developed institutional infrastructure that co-ordinates the activities of these agents, (3). In contrast, the developing countries of today are characterized not only by an insufficient supply and quality of so called task specific economic agents but also by an imperfect institutional set-up (the contractual and legal system, the community relations between the economic agents), (4). These specific conditions would require that the role of the entrepreneur must be assessed in a different perspective in the contemporary developing countries. Thus the present paper, which contains the preliminary analysis of the data collected for a still-continuing study of the introduction, accept ance, and dissemination of technological change and innovations within the firms in various industries, first, determines the entrepreneurial roles in transfer, adoption, and adaptation of technology information in Turkey, a developing country. 37 interviews conducted with 35 firms in two industries (22 firms in machine tools and metal works industry and 13 firms in textile industry) are used as the primary source of data, (5). It, then, points out some of the implications for the educational programs of engineering schools of the developing countries, of the process of developing entrepre-
neurial competence.

2. THE ROLE OF THE ENTREPRENEUR IN DEVELOPING COUNTRIES

Preliminary analysis of data shows that 29.2 percent of the firms surveyed regard the personal experience (informal education) of the entrepreneurs as a very important source of technological information and according to 18.6 percent, the formal education of the entrepreneur is also a very important source. In contrast only 3.5 percent of the firms surveyed would point to the hiring of technical and scientific personnel from outside as a very important source of technological information. Similarly the role of trade fairs and industrial or trade associations in the generation and dissemination of technological information for the individual firm is not regarded highly (6.2 and 7.1 percent respectively). The importance of other sources of technological information both within (technical and managerial personnel other than the entrepreneur) and without (Government technical assistance) the firm is not thought to be significant either (4.4 and 2.7 percent respectively). Thus the entrepreneur within the individual firm appears to be the primary source of technological information and therefore of innovation.

Table 1. Sources of Technological Information Considered to be very Important to the Firm (Two Industries)

<table>
<thead>
<tr>
<th>Sources</th>
<th>No. of Answers</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal experience</td>
<td>33</td>
<td>29.2</td>
</tr>
<tr>
<td>Formal education</td>
<td>21</td>
<td>18.6</td>
</tr>
<tr>
<td>Trade fairs</td>
<td>7</td>
<td>6.2</td>
</tr>
<tr>
<td>Industrial and/or trade associations</td>
<td>8</td>
<td>7.1</td>
</tr>
<tr>
<td>Technical consultants</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>Other sources (Government tech. asst.)</td>
<td>3</td>
<td>2.7</td>
</tr>
<tr>
<td>Other sources within the firm</td>
<td>5</td>
<td>4.4</td>
</tr>
<tr>
<td>Domestic Sources</td>
<td>81</td>
<td>71.7</td>
</tr>
<tr>
<td>Import of Machinery</td>
<td>13</td>
<td>11.6</td>
</tr>
<tr>
<td>Import of raw materials</td>
<td>11</td>
<td>9.7</td>
</tr>
<tr>
<td>Direct technology transfer</td>
<td>6</td>
<td>5.3</td>
</tr>
<tr>
<td>Foreign patents</td>
<td>2</td>
<td>1.7</td>
</tr>
<tr>
<td>Foreign Sources</td>
<td>32</td>
<td>28.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>113</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

According to the table above the personal experience of the entrepreneur appears to be the most important source of technical information for the individual firm. However, when the firms increase
in size the formal education of the entrepreneur becomes almost as important as his personal experience.

It is expected that for the less developed countries of the world today the transfer of technology by various means such as the import of machinery, equipment and processes, import of raw materials, direct transfer of technology, and the purchase of foreign patent rights would be an important source of technological information. However, preliminary analysis of the data reveals that, with exception of the import of machinery and equipment and of raw materials (11.6 and 9.7 percent, respectively, of the firms surveyed think that these means are important), domestic sources of technological information are believed to be much more important. This can easily be seen by a comparison of the ratios in Table 1. For example only 5.3 percent of the firms believe that direct technology transfer is an important source of technological information and innovation, and even fewer firms (1.7 percent) think that foreign patent rights could be regarded as an important source of technological innovation for an extended period of time.

Table 2. Entrepreneurial Motivation in Seeking New Technology (Two Industries)

<table>
<thead>
<tr>
<th>Motivation</th>
<th>No. of Answers</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement of product quality</td>
<td>27</td>
<td>56.3</td>
</tr>
<tr>
<td>Reduction of costs</td>
<td>21</td>
<td>43.7</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>100.0</td>
</tr>
</tbody>
</table>

As far as the entrepreneurial motivation in seeking new technology is concerned, the preliminary investigation of data reveals the following: 56.3 percent of the firms surveyed point out that the improvement of product quality is their primary concern in seeking technological advancement. Those firms that mention reduction of costs as the main factor in their motivation for the adoption of new technology is 43.7 percent. Even though the difference between the cost-cutting and quality-improvement motivations is not very significant it can still be said that the technological dimension in seeking out new technology is dominant.

Table 3. Means of Product Quality Improvement (Two Industries)

<table>
<thead>
<tr>
<th>Means</th>
<th>No. of Answers</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase of new machinery</td>
<td>31</td>
<td>43.7</td>
</tr>
<tr>
<td>Labor skill improvement</td>
<td>15</td>
<td>21.1</td>
</tr>
<tr>
<td>Purchase of better raw materials</td>
<td>17</td>
<td>23.9</td>
</tr>
<tr>
<td>Increased operation scale</td>
<td>8</td>
<td>11.3</td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
<td>100.0</td>
</tr>
</tbody>
</table>

255
As for the means by which technological change geared to improved product quality is achieved, 43.7 percent regards the purchase of new machinery, equipment and processes and 21.1 percent the up-grading of labour skill as very important. Purchase of better quality raw materials and expansion of the scale of operations are emphasized only by 23.9 and 11.3 percent respectively. Again here too the technology consciousness of the entrepreneurs in the country stand out.

Even though our study of the role of the entrepreneur in the introduction, acceptance, and dissemination of technological changes and innovations is still continuing the preliminary analysis of the data presented nevertheless points out the following tentative conclusion: In developing countries such as Turkey an entrepreneur is more technologically oriented than his counterpart in the industrially advanced country, and is usually the primary source of innovations in the individual firm. As a consequence the acquisition of the technological competence on the part of the entrepreneurs, through formal education and/or through an informal process of 'learning by doing', is the key to the problem of 'technological capacity'.

3. IMPLICATIONS FOR THE ENGINEERING EDUCATION

Obviously there is not very much that the engineering schools can do directly to promote the growth of technical competence among entrepreneurs. However some broadly defined policy implications can still be pointed out. These fall into two categories. As far as the formal engineering education is concerned, it can be stated that this education should include:

(a) a broad base of engineering knowledge;
(b) a proportion of related non-technological studies (an integration of technological, economic, and managerial subjects into a creative program); and
(c) an extended period of serious study and experience in industry.

As far as the personal experience (informal education) of the entrepreneur is concerned a close co-operation between the engineering schools and the industry should be developed. This co-operation should include:

(a) short courses in technical and managerial subjects especially designed for the entrepreneurs;
(b) use of faculty as technical and managerial consultants for the industry;
(c) provision of industrial leaves, up to a year, for the faculty; and
(d) faculty and industry co-operation in industrial projects.
4. REFERENCES

(5) Instead of sending out questionnaires we have used the structured interview technique. Basic variables of the study are adopted from the questionnaire used in Ranis, Fei, Cardwell, Baily, *op.cit.* p.86-87.
COLLABORATION BETWEEN INDUSTRIAL TRADES UNIONS AND AN INSTITUTION OF HIGHER EDUCATION

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ABSTRACT

The Unit for the Development of Alternative Products is the result of a partnership between the Lucas Aerospace Combine Shop Stewards Committee and the Department of Combined Engineering at the Coventry (Lanchester) Polytechnic. With a full-time staff of five professional engineers the Unit aims to design and develop to the point of production a range of items which fulfil socially useful criteria rather than merely meet a 'market need'. Such products are hoped to be the means of preserving existing jobs and creating new ones. Students of the Department, as part of their undergraduate engineering course, are collaborating with union members and others to meet the aims expressed by the Unit.
This paper describes the early operational experiences of the Unit for the Development of Alternative Products at the Coventry (Lanchester) Polytechnic. The foundation of the Unit was an outcome of a partnership between the Lucas Aerospace Combine Shop Stewards' Committee and the Department of Combined Engineering at the Polytechnic.

In 1976 the Combine Committee began work to develop a positive response to the possibilities of redundancies in the British aerospace industry. The work resulted in the production of an alternative corporate plan for Lucas Aerospace Ltd. (Lucas Aerospace Combine Shop Stewards' Committee, 1976). The work force were actively involved in preparing the plan which identified almost 150 alternative products which might be manufactured by one or more of the seventeen sites of the company. The products could be categorised into six areas of engineering interest: oceanics, telechiric machines, transport systems, braking systems, alternative energy sources and medical equipment. All were seen to satisfy socially useful criteria rather than merely meet a market need. Although the major impetus for the work of the Combine Committee had been brought about by the members' desire to safeguard their own jobs they very quickly recognised the need to become involved in the promotion of their ideas in the community in general.

This early initiative led to the offer of financial support from a charitable trust which enabled the foundation of the Centre for Alternative Industrial and Technological Systems at the North East London Polytechnic in 1978. The aim of CAITS was to work with the Combine Committee and with other groups in industry to campaign for socially useful production in place of factory closures and redundancies. The work of that Centre has since earned international recognition.

Coventry, or the Lanchester Polytechnic, as it was originally named, was formed out of an amalgamation of three existing colleges. Its foundation in 1970 arose out of a central government policy to expand the post-secondary sector of education. The amalgamation was not without its difficulties which included those associated with the duplication in courses in mechanical engineering. This particular problem was solved by the provision of a new full-time modular credit degree course offering options in a range of engineering subject disciplines. The course was to be operated by a newly constituted department, the Department of Combined Engineering, based upon one of the existing Departments of Mechanical Engineering and supplemented by staff transferred from the other departments. The students were
offered the opportunity to pursue a study programme based upon a combination of disciplines once a general compulsory first year had been successfully completed. One of the major problems associated with modular courses is the danger of students failing to correlate the work of the different constituent modules. In order to combat this the course was developed with a series of compulsory core modules based on what are felt to be the essential skills of a professional engineer. These experiences of operating these core modules of management, experimentation and design have been comprehensively described elsewhere (Breckell, 1977; Coulthurst, 1977; Elcock, 1977; Wheeler, 1980). Attempts have been made to support the vocational aims of the course. Several members of academic staff have spent periods of secondment in industry, others have been engaged on industrial consultancy work, and there have been many instances of student projects being based on real problems (Coulthurst and Elcock, 1980).

In spite of the fact that the Combined Engineering Studies course was designed to meet clearly identified needs and the subsequent attempts to promote and maintain vocational relevance, the course began to find itself in the position of difficulty in establishing a distinctive identity. Departments of institutions of higher education are expected to develop a research base to support the undergraduate teaching. The disparate nature of the range of disciplines which were essential for its fundamental breadth actually mitigated against the development of areas of specialist expertise. In an attempt to create a focus which reflected the nature of Combined Engineering, it was decided to pursue a research/development project which would integrate the constituent disciplines. A series of inter-related projects based upon various aspects of an electric city car were undertaken.

Meanwhile the Combine Committee, encouraged by the success of CAITS at the North East London Polytechnic, had resolved to form a second unit based in the Midlands of England, where many of their members lived and worked. They sought and received an offer of financial help from the Barrow and Geraldine S. Cadbury Trust who supported their aims of converting arms production into socially useful production. Several institutions of higher education were approached with a view to founding the second unit. Even though funds had been offered by a charitable trust this did not prove an easy task and it took over two years before negotiations between the Combine Committee and the Polytechnic began. Once started, however, agreement was quickly reached and following the appointment of a co-ordinator the Unit was opened in September 1981. The policy of the Unit and its general direction are the responsibility of a Steering Committee consisting of equal numbers of representatives of the Combine Committee and the Polytechnic in addition to representatives from the funding agencies. The initial funding was intended to cover the salaries of the Co-ordinator and a second member of the Unit who was to be a development engineer.

The aims of the Unit were to design and develop to the point of
production a range of items, which might be considered to satisfy socially useful criteria rather than merely to meet a "market need". It was hoped that such products may, in addition to reducing the risk of redundancy, actually be the cause of creating new employment. It was always intended that the design and development stages would pay due consideration to the subsequent methods of production.

From the beginning a great deal of emphasis was given to ensuring that the work of the Unit and the Department was closely inter-related. A relatively significant portion of the students' work is project based and it was here that it was felt that the Unit projects might be most effectively introduced. There appeared to be several identifiable areas of work which were of mutual interest and where both the Combine Committee and the Department had previously been active. These were the areas of transportation, energy and medical aids. It was decided to concentrate initially on these areas. In common with most British undergraduate engineering courses all final year students are required to complete a project. In the case of the Combined Engineering Studies Course this may take the form of an individual project or a group project. This means that each year there may be as many as a hundred students engaged in final level project activities. In the first year of operation of the course, twenty three students have undertaken individual projects and another forty three students have been working on group projects which are sponsored by the Unit. In addition to the students, eighteen members of the academic staff have also been involved in a supervisory capacity. The projects have been categorised under three headings: alternative transport, alternative energy and alternative medical products.

Alternative transport includes projects on the electric city car which was already being developed by the Department. A major technical feasibility study on hybrid vehicles is being carried out by a member of the Unit staff and this is supported by seven student projects. Hybrid vehicle development was one of the possible areas which was identified by the Combine Committee's Corporate Plan. Two individual projects and one group design project have considered aspects of development of the road/rail vehicle which had previously been investigated by CAITS. A second group design project also has its origins in the Corporate Plan; an investigation into the auxiliary braking of public service vehicles. The category of alternative energy also takes advantage of the coincidence of interests of the Department and the Combine Committee with projects investigating aspects of windpower, heat pumps and power-pack design. The interest in alternative medical products has been initially limited to a feasibility study of portable kidney machines.

In addition to the support given by the Unit staff the students have also benefited from direct contact with members of the Combine Committee and staff of CAITS. Although the numbers of such contacts have been relatively small, those that have occurred have proved to be extremely stimulating to all parties and have clearly demonstrated the viability of such relationships. The contacts have been made by personal visits, telephone communications, and correspondence. The
The influence of the Combine Committee and the members of the Unions which it represents has, of course, influenced the overall direction of the work of the Department. This contact with trades union membership has been strengthened by the appointment to the Unit of an engineer who was not only a competent technical specialist in the field of automotive vibration analysis, but who was also well experienced in issues concerning the social aspects of the nature and quality of work.

Soon after the establishment of the Unit and once some practical work to implement the aims was in progress, the Steering Committee was approached by the Economic Development Committee of the West Midlands County Council to enquire whether it would be possible for the Unit to support their general policy of re-energising the industrial economy of the Region. The County Council hoped to create employment by encouraging the formation of small businesses and co-operatives mainly by providing a range of supportive agencies and making available initial funding by way of grants and loans. Since the tradition of industry in the Region is based on engineering, it was suggested that the Unit might be able to assume a technical support role to assist potential new industry. Although the original aims of the Unit were completely compatible with the ambitions of the West Midlands County Council it was felt that it was operationally inadequate to make an effective response to the relatively short term nature which their proposed activities demanded. If such a capacity were to be developed it was considered that an increase in full-time professional Unit staff would be required. The County Council agreed to make funds available which would allow the appointment of such staff and consequently three further engineers joined the Unit strength. These additional staff are becoming increasingly involved with the undergraduate student project work whilst still practising as professional engineers themselves. The source of potential products has now spread widely beyond the original sources of the Combine Committee and the Polytechnic. Interested parties have either contacted the Unit directly or been referred by other agencies such as the Coventry Co-operative Development Agency, the Church's Industrial Mission and local authority employment initiatives from places other than the immediate locality.

As described previously, the initial impact of the Unit on the work of the Department was in the area of final year projects. Project work, however, forms part of the first and second level design syllabuses, though in these cases it is introduced towards the end of the academic year. It has long been the practice for the topics of these projects to be as real as is possible within the constraints imposed by educational considerations. The staff responsible for operating the first and second level design courses have selected problems which have their origins in the Unit. One is connected with detail design of part of the electric city car and the other with an automatic door operating device for disabled persons. In terms of student numbers this means that a further 225 students have become involved, albeit in a relatively minor way, in the work.
of the Unit. This influence has not stopped at members of the Department, already students from the Department of Industrial Design have taken problems from the Unit as the subject of individual project work and interest is being shown in similar activities by a post-graduate course in control engineering and by an undergraduate course in engineering design at the nearby University of Warwick. There is obviously a great deal of potential for involving students from a range of courses and institutions in the work of the Unit.

It is felt that the Unit has rapidly established itself as a resource within the Department and within the local community. It has shown itself to be a means of creating and maintaining mutually beneficial links between the two. The activities of the Unit might have led to the opening of windows of the Polytechnic which allow students to view and to relate to the real outside world. The next stage should be to open doors in order that the students might go out and share the problems of society and that members of the local industrial community may come in to share their experience with the students.

REFERENCES


ABSTRACT

The transfer of innovating technology from the research stage is becoming an increasingly important part of the function of University science and engineering departments, and the problems encountered are different from those found in making the internal progression from the research laboratory to production within a Company. The search for effective channels of technology transfer and some of the methods used by the Department of Electronic and Electrical Engineering at the University of Surrey is described in this paper, and the importance of awareness within the University and Industrial Companies that it is a two-way process is emphasized.

RESUMÉ

Le transfert des innovations technologiques à partir du stade des recherches revêt une importance croissants dans les fonctions d'un département universitaire de science et de technologie. Les problèmes qui se présentent ne sont pas les mêmes que ceux qui pose le passage, au sein d'une entreprise, du laboratoire de recherches au stade de la production. Les autres décrivent les efforts faits dans le Département de génie électrique et d'électrique de l'Université du Surrey pour trouver les voies d'un transfert efficace de technologie ainsi que quelques-unes des méthodes utilisées. En particulier, ils mettent l'accent sur les nécessité de faire comprendre, tant dans l'université que dans les entreprises industrielles, qu'il s'agit d'un processus à double sens.

ZUSAMMENFASSUNG

Der Transfer neuer, innovativer Technologie aus der Forschungsphase ist zu einem immer wichtiger Teil der Aufgaben der Naturwissenschaftlichen und Technischen Fakultäten an Universitäten geworden, und die Probleme, auf die man dabei stößt, unterscheiden sich wesentlich von denen des untemehmensinternen Wegs vom Versuchslabor zur Produktionsbank. Dieses Referat beschreibt die Suche nach effektiven Methoden des Technologietransfers sowie einige der Verfahren, die das Department of Electronic and Electrical Engineering
der Universität Surrey verwendet, und unterstreicht die Wichtigkeit der Erkenntnis innerhalb der Universität und in der Industrie, dass diese Interaktion auf Gegenseitigkeitsbasis beruhen muss.

1. INTRODUCTION

The transfer of innovative technology from the research stage is becoming an increasingly important concern of University science and engineering departments, as their research is more and more directed towards the needs of industry: often, in fact, directly funded by specific companies. Industry itself does not find the process of transfer of technology from the research laboratory to production easy and the problems of bringing it from a University research group are very much greater. Encouragement has been given by the Government in Britain, and mechanisms set up to aid the transfer of basic research from the Universities to industry, but the search for effective channels continues, and this paper concerns the relevant work of the Department of Electronic and Electrical Engineering at the University of Surry to achieve the necessary close relationship with the industry we serve. We would begin by emphasizing that it is a two-way process.

2. DIRECT RESEARCH BY THE DEPARTMENT UNDER CONTRACT

Twelve years ago the Department set up a special Industrial Electronics Group (IEG) to work solely under contract from industry and Government departments. This work is specified by, and the progress controlled by, continuous liaison with the customer.

The Group offers three basic services:

- Research prototypes: examples of these are: (a) a general purpose 300 point digital correlator designed as a research tool into communications modulations techniques for use in a national research laboratory, (b) a multipath HF propagation simulator designed to enable systematic evaluation of HF communications systems in the presence of multipath, particularly data links.
- Small Batch Production of Special Equipment: for example a special side band VHF telemetry system was developed to meet a specific requirement in a marine testing tank with up to 5 way diversity. Development was carried through to production standard and 6 models supplied to the customer.
- Three-way Agreements involving the University Group as the contract R and D organisation funded for a particular link by a Government research establishment with an industrial company committed to the production engineering and marketing of the product on a licensing agreement. Such an agreement was reached on the development of an advanced performance non-recursive digital filter. Joint arrangement, supervising small batch production by local manufacturers, are also used.
The academic staff of the University are involved as consultants and often as project leaders but the importance of a strong technical design and development team employed largely on this work cannot be over-emphasized. The need to speak the same technical language as the customer, to appreciate the importance of cost control, and the time element, is one of the most difficult things to achieve but University staff can hold their own particularly if they are helped towards this outlook through, for example, joint research programmes with industrial staff, and regular discussion periods spent in industrial surroundings.

Similarly, visiting staff from industry can help by contributing their expertise as consultants. For instance, a Visiting Lecturer is now a leading member of a Group Study team looking into road traffic sensors on behalf of an industrial client. This particular study is a broad collaborative project embracing the client's industrial need; electronic expertise from the Department of Electronic and Electrical Engineering; transportation expertise from the Department of Civil Engineering; and applications 'state of the art' expertise from the visiting staff member.

3. SHORT COURSES AND HIGHER DEGREES

The provision of short courses for up-dating or retraining industrial staff is a valuable method of increasing the two-way flow of awareness of what the Universities have to offer, especially the personal contacts made. For instance, industrial contracts established by the attendance of senior industrial staff at short retraining courses led to the establishment of sponsored research and development projects in the fields of:

- Acoustic emission as a technique for airframe life and fatigue testing.
- Speed control of induction motor fans for ventilation and environmental control.
- Special environment instrumentation for a British Antarctic expedition, etc.

Higher degrees, arranged on a collaborative basis can also lead to viable products and a continuing relationship. An Example of this is the collaborative PhD project set up with the National Coal Board, leading to the award of a PhD to the collaborative student; development of a market viable underground communications system; and the establishment of a continuing joint research programme with the University staff into the general problems of mining and associated industrial communication problems.

4. MINOR PROBLEMS

The question of difficulties arising, for example, over joint patents or royalties, can be overstressed. Providing that these
matters are discussed, made clear and agreed upon from the outset, there need be few problems.

Publication rights can only be relinquished by a University Department if agreed in advance with the staff concerned. Possibly a delay of say a year may be enough to satisfy the need for industrial security before the launch of a new product and the need for an academic to publish his part in it.

This particular potential problem has worried academics needlessly in the past. The scale involved is indicated by the facts which are that in 12 years of active industrial contract research we have had only one case where a sponsor requested a year's delay in publication to synchronize it with the launch of the product. In one case a sponsor has requested that a project should not be the subject of a publication on security grounds.

Over the same period, over 36 publications and conference papers have been produced on aspects of the work of the IEG.

5. SCIENCE PARKS

The American development of science parks around Universities, often by University staff themselves, is now spreading. Surrey University is at present negotiating with the local authorities to establish a Science Park on University land at Guildford and there is a good chance that the proposal will be approved.

Several existing units would provide a basis for the venture. For instance: Robens Institute of Industrial Health and Safety; the Biotechnology Unit; the Space Structures Research Centre; the Structural Plastics Unit, etc.

Production would not be permitted so that the effective transfer of new science and technology to industry would become even more essential, and the need for mutual University/Industry collaboration must be fostered both by the tried and true methods described, but also by increasing and intensifying staff training in good management practices in the Universities at all levels. This latter point has led to the establishment of an Industrial Advisory Board by the Department of Electronic and Electrical Engineering at which senior Industrialists meet regularly with academic staff and present a valuable industrial viewpoint. This is an important aspect of the overall decision process.

6. CONCLUSION

There is no doubt that because of the inherent differences between the function and operation of the Universities and industry, there is a problem in knowing when and how to transfer research results to industry. Industry should not be afraid to approach the Universities for help, and should ensure that they know what research
is in progress. The Universities should not be afraid of involve-
ment with industry.

The vital point of collaboration is quick response by both mem-
ers of the collaborative partnership.
NEW PERSPECTIVES FOR SANDWICH COURSES AFTER TWENTYFIVE YEARS

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ABSTRACT

A brief historical survey of the development of sandwich courses. The development of industry-education interaction and how this affects the attitudes and outlook of staff and students: exemplified in chemical engineering education at the University of Bradford, United Kingdom.

The development of the "feedback", industry to university, and how this has created initiatives for a new course, Industrial Technology, with its associated challenges and problems, satisfying more effectively than before the present and future needs of manufacturing industry. The effect of "feedback" on the development of post-graduate research.

Some limitations and possible educational disadvantages of the industry-institution interaction.

RESUME

Une revue concise de l'histoire et le développement des cours "sandwich". La réalisation de l'entretien entre le monde industriel et l'éducation. Comment cet entretien influence les attitudes et la philosophie des enseigneurs et des enseignants: l'exemple de l'éducation des ingénieurs de chimie à l'université de Bradford, le Royaume-Uni.

Le développement du "feedback" entre le monde industriel et l'université. Comment ce "feedback" a créé l'initiative pour un cours nouveau, "Industrial Technology", avec ses propres problèmes et demandes, un cours qui satisfait plus effectivement que d'avance les exigences actuels et futurs de l'industrie. L'effet du "feedback" sur le développement des programmes de recherche.

Limitations et désavantages qui peuvent se manifester dans les liasons entre l'industrie et les instituts pedagogiques et professionnels.

ZUSAMMENFASSUNG

Ein kurzer historischer Überblick über die Entwicklung von Teilzeit Kursen. Die Entwicklung der Interaktion von Industrie und Bildung, und
Ihr Einfluss auf die Haltung von Lehrenden und Lernenden, dargestellt am Beispiel der Ausbildung in Chemieabteilung an der Universität Bradford Vereinigtes Königreich.


Einige Probleme und mögliche bildungspolitische Nachteile der Interaktion zwischen Industrie und Institutionen.

1. BACKGROUND AND PROBLEMS

There are about 30,000 sandwich course students in the United Kingdom today, of whom rather more than half are attending poly-technics and other colleges. Since the mid-sixties there has been a rapid increase in student numbers but recently the rate of increase has slowed down, and for the next few years it is likely to be negligible. Nevertheless, the sandwich course method of undergraduate education is an accepted part of the education system. Graduates from such courses appear to be satisfying the needs of industrial and other employers and in a time of economic recession they are beginning to have the edge on other students in employment and career prospects.

In the past there has been a great variety of courses in higher education which have sought to combine in various ways theoretical instruction in one institution with practical experience in another. Examples are medicine, where such practice was institutionalised many centuries ago, and mechanical engineering: most professional mechanical engineers in the first half of this century qualified through part-time study.

Modern sandwich courses originated in Glasgow, Scotland, in the nineteenth century and in Sunderland, England, in 1903. The Sunderland pattern was taken up by Dean Schneider in Cincinnatti, U.S.A., where the more egalitarian attitudes of the time enabled co-operative education, as it came to be named, to flourish. The elitist attitudes of academic professionalism in Britain tended to hold back the development of such methodology until the mid-sixties, when it became obvious that the U.K. was falling behind in its education of professional scientists and engineers. It is rather more than twentyfive years since Lord Hives produced his report on the expansion of tertiary education and the recent development of integrated education began. Twentyfive years is a reasonable period to judge the efficacy of an educational experiment of this type, although critical assessment is difficult, as there seem to be almost as many differing course patterns as there are courses. However, there are two main types of sandwich course in the U.K. The so-called "thick" course involves one or more periods of one year in
industry. Two major problems emerge from this pattern: (i) the rate of evaporation of theoretical knowledge acquired at university increases with time and (ii) the rate of learning arising from the new experience with one company falls, the fall increasing with time. The "thin" sandwich involves two or more six-month periods in industry - preferably with different organisations. It can be argued that six months with different organisations goes some way towards countering the two major problems of the "thick" sandwich course, as well as helping to lay the foundations upon which an understanding of such challenging problems as the transfer of technology from one manufacturing or production process to another may be built. This paper therefore deals primarily with the "thin" sandwich pattern of tertiary education.

In the early days, because of lack of experience and understanding of educational methodology, the structure of "thin" sandwich courses was such that often the industrial and teaching periods were not really complementary and the only claim to integration was that the different parts were sequential. The name "sandwich" course in many ways aptly described the situation. Thanks to the conscientious and continuous efforts of staff to maintain educational supervision of students during their industrial periods, there has been a steady, consistent move towards a much more unified course, in which theoretical teaching in the university and practical experience in industry are coordinated, creating a much more interactive, integrated whole. It must be recognized, however, that the complete integration of the theoretical and practical aspects of a student's education can never be fully realized, because of the inevitable time lag between the dynamic nature of industry as it spearheads technical advances, and the non-instantaneous feedback of this process into the university teaching programme.

2. EDUCATIONAL ADVANTAGES OF INTEGRATION BETWEEN THEORY AND PRACTICE

It is, nevertheless, possible to develop an educational programme in which the students' intellectual progress in industry and academic development at university are complementary. It is this kind of development which began to take place in the School of Chemical Engineering at Bradford University some twenty years ago. Such a course must be carefully designed to enable students to understand the principles underlying industrial experience and to utilize industrial experience to reinforce the relevance of their academic work. Through the pedagogical effects of careful coordination, the more rapidly maturing sandwich student by contrast with the full-time student is afforded the invaluable opportunity of consciously recognizing the creative interaction between theory and practice in the totality of the educational experience. This invaluable awareness does not develop in traditional educational regimes, in which laboratory work and teaching both occur within the university, isolated from the economic and organisational pressures and the technical challenges of the world of industry. Appreciation of
these constraints and challenges plays an essential part in education for entrepreneurial success and helps to develop practical creativity and initiative.

The acceleration of learning which a well-planned sandwich course can effect is not surprising when it is recognized how, in the early days of evolution, man was able to separate himself from the rest of his natural environment, and to develop his unique creative powers. Anthropological studies, starting with the important work of Gordon Childe, have clearly established that man separated himself from the environment by practical effort and that this led to his consequent cultural development. The natural learning process which gave rise to the evolution of the human brain is initiated by practical activity. It is practice, as it develops to meet the challenge of social need, which stimulates the feedback between action upon phenomena and the conceptual understanding of the phenomena.

3. NEED FOR CONSCIOUS APPLICATION OF EDUCATIONAL PRINCIPLES OF INTEGRATION

The social experience of the learning process as a form of coordinated interaction between theory and practice had never been consciously applied to engineering education until the sandwich course gave this opportunity. It is still standard practice on most university courses that students are expected to accept the theory first, followed, on graduation, by practical experience. They are, therefore, dependent on unnatural learning methods, with inevitably random and often inefficient results. Yet the concept of integrating theory with practice is only the first step towards appreciating why integrated sandwich course graduates are more creative, mature, self-disciplined and socially and economically more aware than graduates from traditional full-time courses.

The interaction of both students and staff with industry has deeper implications, which must be brought to the surface and studied if they are to be scientifically applied in the teaching-learning situation and thus lead to the development of ever more appropriate courses and methods. The integration of theoretical work and industrial experience ensures that a course of study will not ossify, that it will have relevance and use within the changing social context, and will produce graduates who can anticipate and plan for future developments. The interaction between industry and university can lead, if methodically studied and utilized, to the development of guidelines for research programs, which will in turn contribute to the constant up-dating of undergraduate teaching. Thus there evolves a further pattern of social interaction between industry, research, teaching and learning, which is intellectually creative and stimulating for all concerned.

4. INDUSTRIAL TECHNOLOGY: A NEW RESPONSE TO THE NEED FOR INTEGRATION

It was in direct response to the perceived needs of the industry-
education interaction that the undergraduate degree course in Industrial Technology and Management was developed. The establishment of the feedback system between industry and the university began to forge an important new relationship which gave staff, students and industrialists new perspectives and offered the opportunity to improve education, research and industrial performance. From the outset, staff in the newly-established school sought to diversify the organisations in which students obtained their industrial experience, from the more traditional textile, coal-mining and engineering industries to the modern nuclear, petro-chemical and computing fields. Because of this very diversification, it became apparent that the whole of industry was primarily concerned with improving productive efficiency. This improvement, however, could only result from educating personnel who were capable of recognizing the interrelated nature of problems and of seeing the totality of the productive organisation, from the point of entry of both people and materials to the exit point and beyond, in the sale and distribution of products. It became clear that the traditional single discipline education was quite inadequate for the new tasks facing industry. These demanded that employees develop new and changing specialisations in order to solve the multiplicity of problems with which modern industry is faced. Thus the feedback system had created a new type of educational challenge. It was obvious that a new unity of study was necessary, which would draw upon the concepts and principles of a whole range of single-discipline subjects and apply these to the study of production. This, it was hoped, would create the necessary integrated theoretical background required of graduates moving into productive industry. At the same time, the new course would have to educate creative, innovative minds, capable of developing on a flexible basis those specialisations which would satisfy the immediate need of the organisation as well as ensure its future success.

This educational problem has now been theoretically solved through the philosophy and structure of the Industrial Technology programme of studies. As with all dynamic educational developments, the practical solutions can only be approached, not finalised. Closer approximation to meeting the educational and industrial challenge has been accomplished over the fifteen years during which the course has been operational. Some proof of its success with industry lies in the fact that employers, even in the present difficult economic situation, continue to find the required variety of industrial experiences for students and that graduate employment remains consistently better than from single disciplines. The course has now passed from the experimental stage to recognition as an invaluable professional education for students wishing to make a career in industry as well as for those who decide to undertake further study or research.

During their course, students are presented with procedures and principles drawn from a whole range of disciplines, from economics, sociology, the natural and engineering sciences, computerisation, reliability and quantitative techniques. The selection, co-ordin-
ation and presentation of the course material present a formidable but exciting challenge to the educator, who has to reconsider his or her own single-discipline conditioning in the context of the new integration of knowledge. In keeping with the central and formative role of production in society, the nature of production itself has become the conceptual focus of the curriculum and the main stimulus towards methodological as well as philosophical integration. As production is by its very nature dynamic, this concentrates the attention of staff and students alike on the nature of change and the need for innovation. Special attention is paid to the complex challenges of technological innovation and the transfer of new technologies to traditional industries. Students are encouraged to apply the principles involved in these processes to their project work. They are expected to draw upon a working knowledge of industrial organisations, gained from a combination of practical experience in industry and related academic study. The projects at their best reach a very high standard. They begin to form the basis for new specialisations based upon the integration of disciplines. It is interesting, in this context, to note that research in the associated post-graduate school is largely carried out in the pioneering, and necessarily interdisciplinary, field of risk and reliability, including human risk. The school was the first in the U.K. to be invited in 1981 into membership of the European Reliability Data Bank Association (EuReDatA).

The feedback from industry still operates, directing the curriculum today towards greater emphasis on computerisation processes and on solving the complex problems of communication in industry. As industry itself changes, there can be little doubt that these changes will not just be met, but accommodated - and even initiated - by graduates from the course, and that the interaction between the university and industry will be maintained.

5. PROBLEMS AND RISKS IN THE EDUCATION-INDUSTRY RELATIONSHIP

However, this interaction also carries with it the dangers of possible attempts at domination by industry, arising from a failure to look beyond short-term interests. The narrow attitudes of some sections of industry are inimical to creativity and innovation, especially when they demand highly trained technicians instead of the creative people scientists and engineers must be. Such attempts at domination can only be to the detriment of industry and of the university's longer term academic development.

Consistent, therefore, with our best traditions of intellectual integrity and academic freedom, and with vigilant awareness of the corruption which can penetrate commercial and industrial life, research contracts and consultancies, as well as industrial experience, must always be critically examined.

It must also be said that although traditionally the professional engineering institutions have contributed greatly to the education and practical competence of engineering students, they, too, can act
as a brake upon innovation and creativity. This can happen if they fail to keep abreast of developments in either industry or education, or if they inhibit the dynamic interactions between them. Awareness of these problems, however, enables the effects to be minimised in the interests of student education and the consequent usefulness of the engineer to industry and society.
The technically qualified person is an important agent for innovation and change and education is a key factor in equipping him to fulfil that role.

The paper describes recent initiatives at Manchester and Cambridge which seek to meet this educational requirement.

The Manchester experience includes involvement in a "new enterprise program" sponsored by the UK Manpower Services Commission and the "Greater Manchester Enterprise" sponsored locally. At the Manchester Business School an entrepreneurship project forms an integral part of the MBA programme.

At Cambridge a new course in manufacturing engineering has provided the opportunity to bring an entrepreneurial dimension into undergraduate teaching via a product-based business proposal project. More broadly the infrastructure building up around the course is designed to produce an engineer with a sound industrial and business outlook.

A post-graduate programme is tackling innovation and change in an established manufacturing operation.
ABSTRACT

The attention is drawn to a method of technology transfer which is often overlooked. Technology transfer, especially into small- and medium sized enterprises (SME's), is stressed in university circles. Pre-eminently in this case the knowledge transfer by a senior student with a master's thesis project in industry is very effective. Advantages and disadvantages are discussed.

RESUME

Le gouvernement oblige les universités de réaliser le transfer de leur connaissance technologique vers l'industrie en général - vers les petites entreprises et les entreprises moyennes en particulier. Il se recommande donc de stimuler les étudiants dans leur dernière année de passer leur stage dans une telle industrie. Les avantages et les inconvenients de ce système sont discutés.

ZUSAMMENFASSUNG


"The best method for technology transfer between Technological Universities and Industry is by students doing their master's thesis project in the industry".

Technology transfer: Why? for Whom?

In 1979 the Dutch Government published a report (1) about the necessary innovation in the industry. In this report a new direction was indicated for future technological innovation in the Dutch society, and by doing so the government followed rather late the examples
already given in several other western countries. Recommendations were mentioned similar to those elsewhere, to develop again a flourishing competitive industry, which has to take over the task of the diminishing income resources of the - in the future - declining natural gas production.

One of the recommendations was to make the R & D efforts from universities and national laboratories more useful to the industry. Traditionally the Dutch society has always spent a larger part of the R & D efforts on the universities and laboratories than on the industry, and obviously the message was now to direct this R & D effort more into the market. This is done by diminishing the free spending facilities for the universities, so that researchers have to seek their grants and research orders from the industry, and by starting up facilities for transfer of know-how from the scientific circuit into the industrial circuit. Large firms have had all along good connections with the scientific university research, and at the same time the potential capacity of the small- and medium sized business in resisting the economic crisis is more and more recognized (2), so that the emphasis was laid on technology transfer into those small- and medium sized firms (SME's).

Those firms usually have none or only a few graduated engineers on the payroll, and that is also the reason why there is a certain restraint to make an effective contact with university researchers. To improve this situation the above mentioned technology transfer into small-sized firms has to be intensified by introducing transfer points in the universities and by establishing so-called innovation centers. Those ideas make us almost forget that there is a steady flow of know-how from the universities by delivering so many graduates a year to the industry. True enough this is a one direction flow, and up till now mostly to the large firms; it is only recently that because of higher unemployment rates the graduates also start looking for jobs in smaller firms.

However, as said before, in those firms is also a reluctance against engaging university graduated engineers, coming from the idea that they are too expensive or too left-handed. In this situation there is an interesting possibility to overcome those barriers: by students who are doing their master's thesis project in industry.

Master's thesis project

In our department of Industrial Design Engineering much emphasis is being laid on the study on the process of systematic product development in or for industry. More than in Industrial Design schools elsewhere the technical and managerial aspects of the innovation process are being stressed; besides, this department is more development-orientated and less research-orientated than most of the other departments in our University. Reddaway mentions in his survey of Engineering Design Education (3) at least two fairly distinct Design Methodologies: the problem-solving design methods in North-America and the U.K., and the more thorough methodical design, main-
ly practised in Germany, and also in Holland. However, this industrial design study is more problem-solving, more design-orientated. Design- and product development is strongly connected with and influenced by production surroundings and market experience, and as these are not available at a university, one has to simulate this situation as well as possible. However, the reality is often too complex to be imitated. Therefore we are of the opinion that a training project in the industry is the best conclusion of this curriculum leading to a masters degree (4,5).

Most of our students agree with this viewpoint and welcome the opportunity to do at last a project in reality after so many years of training. Those projects take at least 8 months, as specified in our curriculum, but as in most cases the student is paid as an employee on a minimum basis nobody complains when the minimum obligatory period of 8 months is sometimes extended up to 14 months! Until now about 150 students have taken their degree in this way, and quite a number of those stages have been within small- or medium-sized firms. In that case we usually start with a two month orientation, and only after that we can define the problem or the exact task of the student. Sometimes the problem which the firm has brought up in the beginning has then changed into another! If possible, we try to go through a part or through the complete process of systematic product development, starting at the information sampling phase, the product planning, design specification, and ending with the prototype drawings ready for production. After that the student gives his presentation, gets his master degree and finds himself a job somewhere else, but sometimes within the same firm. This means that for a small firm such a project is an attractive method to hire university capacity, to introduce oneself into the university know-how circuit without too much cost and risk.

The best method of technology transfer

There are different methods of transfer of know-how. In scientific circles the literature and visits to symposiums are the usual methods, but in industry, especially in the SME's, people do not have too much time and certainly not for reading literature. So know-how transfer should be accomplished by personal contacts which are indeed their strong point, especially having contact with the market, with the customers. However, because of reasons mentioned above it is difficult for them to establish contacts with the scientific circuit. And if it is at all possible to define the problem, and to find the place in the university where they can put their question, then there is the synchronising problem: at the university everyone has his workscheme and is not ready to pick up the question immediately, whereas the entrepreneur of the small firm needs his answer tomorrow, if not today, because he promised to deliver tomorrow. So one should not expect too much of this
method of technology transfer, the more so as there are numerous
consultant engineers and laboratories which are well equipped to
give a good and fast service on this point.

There is another method of personal know-how transfer suggested and
that is by staging university employees temporarily in the industry.
Perhaps this method works for example in the USA, where the teaching
period is only a part of the year, and in the other part the teacher
has the possibility - and financially is mostly obliged - to work
in the industry. However, I don't see this as a real possibility in
Holland, where teaching is a full time job and just now the teaching
period is enlarged and spread over 40 weeks a year!

Far better and easier is it to stage a senior student in the firm.
He is still flexible, usually has no obligations and is quite
willing to move to another town to fulfil a temporary job at a low
salary. This student knows a lot of theory, is eager to practise
it and has still enough patience to listen to less scientific but
more practically orientated people, so typical of the small firm.
The student is not seen as a threat by other employees of the firm
(mostly not of university level!) like a foreign consultant, and
therefore problems are discussed more freely. Everyone tries to
teach the student to a good end, and since good teaching is never
a one-way transfer, the people around the student learn from this
discussion.

The student, however, absorbs the situation and the problems, and
he is still being supervised by his teachers. So they have to spend
some of their time to meddle with his problems. Often the student
seeks and finds experts somewhere else in the university, and they
too see the advice seeker as student, not as an outside client with
whom one has to be patient or polite, so that an excellent knowledge
transfer occurs. It is astonishing how much information and coope­
ration a student can get in this situation.

And not to forget: the student is usually on the payroll, he is
motivated, spends 100% or more of his time on the problem and is a
very effective workhorse!

This master's thesis project is not to be compared with practical
stages in the freshman years, where the industry often finds the
student more a burden than a useful co-operator. Although we never
guarantee definite results to the firm, only a certain amount of
effort, it is our experience that afterwards it is mostly much
appreciated, the firms do come back again or try to engage the
graduate engineer.

Other advantages

Without much effort the quantity of knowledge transfer in the
industry is enlarged. One can say "enlarged", because it is the
basic purpose of a university to deliver graduate engineers, and
by doing so to accomplish a continuous knowledge transfer.
However, this method uses a part of this large quantity of students as a second output - which means a great volume of turnover. The method is also to the benefit of the student; he likes it, there is no industry-hostility as we felt 10 years ago in student circles, and it eases for him the transition from the education period into the social productive period of his life. This transition should not be underestimated: we live in a society where we keep young people twenty years or more in an educational system, so we should not be surprised when they at last have wrong ideas or fear of the working society, fear of making his degree true. This stage gives the student the opportunity to make acquaintance, to exercise the theory in practice, but still as a student and with the knowledge that errors are allowed!

Very effective is also the feedback and knowledge transfer into the university. It is a pleasure to see the students grow into their new position sometimes, and it stimulates to readjust study-programs and educational methods. Next to that it keeps the teachers informed about the goings-on in practice. In our department we try to enroll teachers with experience in industry, preferably in product development or design; however, after 5-10 years this experience is turning obsolete, has to be refreshed and this can be done by the student as an intermediary.

Disadvantages

Doing a master's thesis project in industry is not possible nor is it emphasised in every technical study. Especially in the research-orientated or theoretical disciplines there is less enthusiasm for this method. This has several reasons: one of them is that teachers believe to have less influence on the necessary scientific level of the student's work, especially when the project is to be done in a small firm. They even maintain that it is not possible to do scientific work in such a situation. This may be right if it is not the intention that that study delivers graduated engineers for jobs in the small firms. The underlying reason is, however, mostly that a student working in industry can not spend his time on research projects in the university. Some of those research projects can only continue because of the availability of abundant cheap student labor. Another reason may be that it demands considerable effort and willingness of the university staff to acquire sufficient contacts with industry for those projects. The projects often take longer than foreseen in the curriculum, there are other terms, and that means that the teacher has to adapt himself to the needs and the possibilities in the industry. Although the results are sometimes very motivating, it also implies that the university staff has less opportunity to do research work, and to publish, which is estimated so highly in university circles.
Conclusion

The results of this final year stage are encouraging. Several new products developed in this way are now on the market; approaches and impulses have been given for innovative behaviour in quite a number of industries, especially small- and medium sized firms. For those firms this method of technology transfer means a step without too much risk, the expenses are overseable, the process is to be influenced; such an enterprise appeals to the small firm entrepreneurs.

The students are enthusiastic about this possibility, they work quite motivated as they know that a good project gives them a good reference for their further career. Perhaps this facet of the study is also the reason why it attracts so many freshmen at the moment. A year ago we were compelled to put a numerus fixus in the enrollment, which is exceptional for a technical study. The faculty believes that this stage is an indispensable conclusion of the curriculum, although the result is that it is difficult to find some students willing to do a research job in our own laboratories. We want to continue this method, but as our normal 5 year curriculum has to be shortened to 4 years in the near future, this stage has to be done in a period of 4 months. This is too short for a worthwhile project, and we hope to extend a part of the necessary time for those stages above the allowed immatriculation time. Those efforts seem to us to be quite in line with the objectives which the Government pursues in their Innovation Report by stimulating technology transfer.

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   In: "Konstruktionsmethodik in der Uebersicht", Nr.5 der Schriftenreihe WDK (Workshop Design Konstruktion) Zurich.
The subjects of the Small Group Discussions which are planned in addition to the four main themes are:

1. Courses
2. Case Studies
3. Political aspects of innovation
4. Biotechnology
5. Marine structures
6. Hydraulics
7. Curriculum Development
8. Innovation
9. Information
10. Continuing Education
11. Mathematics
12. Academic Exchange
13. Computer Programs.

Several high quality papers on Courses and Case Studies which were submitted for the Conference could not be accommodated in the four parallel sessions on the four main themes. These papers are now presented under those headings as part of the Small Group Discussions. The Small Group Discussions 7 to 10 will deal with topics of SEFI Working Groups already established. SEFI has under consideration the establishment of working groups on the subjects 11, 12 and 13.

As a starting point for the discussions convenors assigned for each group have prepared the following papers.

The Groups are expected to formulate conclusions and/or recommendations which will be presented to the Administrative Council of SEFI and eventually included in an edition of the SEFI Journal.

During the Conference two meetings of each Small Group have been planned. The Conference participants have been requested to indicate their preference for participation in the Small Group Discussions.
"Genius is 10% inspiration and 90% perspiration" and the same could apply to lower levels of invention and innovation. Whereas most engineering courses subject students to the "perspiration" they usually neglect the "inspiration". In fact, most courses seem to train students to fit neatly into existing society, university and industrial positions rather than to produce creative engineers.

Part of the reason for this might lie in the fact that, of the three areas of ability required by innovative engineers viz. knowledge, skills, and attitudes, the former has the major emphasis in every course. Skills, including those of creativity and decision making, come poor second while attitudes receive almost no attention. Unfortunately these skills and attitudes are vital for entrepreneurs.

It has frequently been stated that engineers are uninformed or disinterested in topics such as economics, financial management, personnel management, law, ethics, etc. and that such subjects should be included in all courses - especially if entrepreneurs are to be encouraged. In general however, little more than lip-service is paid to them.

Arising from viewpoints such as these the following questions suggest themselves:

1. How can creativity be stimulated in Engineering Courses?
2. Should education move away from the usual attempt to teach all aspects of the engineering specialism towards a more active learning approach to integrated engineering problem solving?
3. How can potential entrepreneurs be identified and encouraged?
4. Should interdisciplinary programmes/projects be developed between Depts. of Engineering and Business/Management - and, if so, how?
5. How best can education be provided at the individual entrepreneur's time of need - and when is it this time?
THE PRODUCT ENTERPRISE - A MAJOR CO-OPERATIVE PROGRAMME IN PRODUCT INNOVATION

England

ABSTRACT

Students of electrical and electronic engineering at the University of Bath can now follow a special course sponsored by electrical companies in the United Kingdom. Time on this course is given over to the study of the 'Product Enterprise', the aims of which are:

- To instil an understanding of the development of new products; and
- to develop the skills needed by professional engineers to enable them to play an effective part in product innovation.

The method of learning is based on an activity programme which centres on the students' own attempts to carry out, over a two-year period, a full product development task.

The paper describes the programme in detail, drawing particular attention to the important liaison with industry which is maintained throughout the programme.

RESUME

Les étudiants en Électricité et Électronique de l'Université de Bath ont maintenant la possibilité de suivre un cours spécial patronné par des entreprises d'électricité du Royaume-Uni. Dans ce cours, une partie du temps est consacrée à l'étude du 'Product Enterprise', les objectifs sont:

- D'inculquer une compréhension du développement des nouveaux produits; et
- de développer les compétences nécessaires aux ingénieurs professionnels pour jouer un rôle effectif dans l'innovation d'un produit.

La méthode d'enseignement est basée sur un programme d'activités centre sur les propres tentatives des étudiants pour mener à bien, en deux ans, le développement complet d'un produit.

L'article décrit le programme en attirant particulièrement l'attention sur la liaison importante avec l'industrie maintenue du programme - tout au long.


1. BACKGROUND

A new industry-linked degree course in Electrical and Electronic engineering has been developed by the University of Bath in collaboration with GEC Marconi-Bolton et al. (1981): its first intake started in October 1980. The main aim of the course was to instil in graduates the skills and attitudes needed for early effectiveness as professional engineers in industry. These skills were seen by our industrial collaborators to be lacking in the majority of graduates of traditional full-time and sandwich courses.

This aim is not new, and many institutions and companies have devised improved undergraduate courses designed to attain it: the incorporation of lecture courses in management and the social sciences and the introduction of design studies and project work - all have gone some way towards the provision of an element of 'professionalism' in University courses. The programme described in this paper will, we are confident, achieve greater success in attaining the aim.

2. UNDERSTANDING, SKILLS AND ATTITUDES - A CO-ORDINATING THEME

The skills and attitudes required by a competent professional engineer are discussed at length by Bolton et al. (1981). If at least some of these were to be developed during this course, then a coordinating theme was necessary to enable students to see the relevance of their lecture courses in engineering and the supporting subjects (management social sciences, etc.) to their chosen career of
professional engineer. Initially 'design' was considered as this theme; but it soon became clear that this choice would result in a restricted view of the engineer's role - a follower of specifications rather than a professional who could effectively play a part in any stage of the product innovation process from perception of market needs to installation and after-sales support.

The theme had to encompass the entire innovation process, and the title 'The Product Enterprise' was chosen as being a more accurate description of what was needed.

3. THE PRODUCT ENTERPRISE PROCESS

There is an extensive literature on product innovation which contains many 'ideal' models of the process. Our first task in designing a programme, therefore, was to select a model of the process which was sufficiently general to illustrate the essential stages, the important variables and the interplay between companies, departments, markets and regulatory bodies. It was also necessary that students should realise that any product enterprise involved the consideration and assessment of such factors as market needs, risk, financial outcomes, time and legislative constraints: technical solutions which, however ingenious, ignored these factors did not contribute to successful innovation. Although in practice the product enterprise process involves many iterations, it needs to be divided into discrete stages so that milestones can be set up for effective management. The stages chosen for the student programme were:

- Project Definition and Feasibility Studies;
- Project Planning, Design Specification;
- Design;
- Design consolidation;
- Production, installation and maintenance instruction;
- Project summary and final report.

4. METHOD OF LEARNING

Having set our sights on developing an understanding of the Product Enterprise process and instilling in students at least some of the skills and attitudes needed to play an effective part in successful product innovation in industry, it was agreed at an early stage that a substantial small group activity programme was needed to provide the essential motivation. Earlier experience in the University (Bolton, 1978) had confirmed the motivational effectiveness of such programmes among engineering undergraduates; and also showed their effectiveness in developing the skills of group working and communication which were seen to be essential (and usually lacking)
in the engineering graduate. But a University activity programme alone is not enough. All students are sponsored and spend ten weeks in each of the three summer vacations with their sponsoring companies. These industrial periods are more tightly structured than is commonly the case; and students are given assignments to complete on the themes of production, commerce, and design aimed at providing in depth knowledge of particular aspects of the product innovation process as well as providing those necessary insights into the general industrial atmosphere which are given by any industrial placement.

5. THE ACTIVITY PROGRAMME 1981-3

The programme which started in October 1981 is divided into the six stages listed above. About 50 hours of tutorial time are allocated to each stage and students are required to complete specific tasks at the end of each stage.

The first 5 hours of the programme are devoted to an introductory case study and the reading of a study pack describing the innovation process and containing a selection of readings from the literature. This introductory period aims at consolidating the insights already acquired in a pre-university induction course run by the sponsoring companies, a 20 hour first year tutorial programme on the theme 'Quality in Engineering' and the first 10 week industrial vacation period.

The introductory case study was about a fictitious company which had embarked on new product introduction with disastrous results; the aim was to encourage discussion and reading about the minimum essential steps and information exchange necessary for success. Groups' answers to the case study questions showed a fair understanding of the essentials of the process and of the fictitious company's mistakes in going through it.

After this introductory activity, Stage 1 of the 1981 activity programme began with student groups being invited to play the part of consultants to a fictitious mechanical valve manufacturer, recently taken over by a multi-national corporation, which wished to explore ideas for new electrical or electronic products which would be saleable in its existing markets. While a hint was included in the invitation about the Managing Director's personal choice, no constraints other than those of the market and money available were included.

At the end of Stage 1, after testing a wide range of ideas, the groups presented their chosen products together with feasibility studies. The choices included two tank level monitoring systems (the Managing Director's choice) and two ranges of valve actuators. Although it had earlier been agreed to be desirable to steer all groups toward a tank level monitoring system, the cases made by the groups which had proposed the valve actuators were convincing,
and in the interest of maintaining morale, they were allowed to proceed.

The second stage, requires groups to produce design specifications outline quality plans and a project plan before design proper begins. The design specifications which have been presented have been most encouraging: most of the important points have been covered and although some figures have needed correction, the authors have seen design specifications in the real world of industry that were significantly less comprehensive.

During Stages 3 to 6, drawings, models, production and testing instructions, installation and maintenance instructions and sales literature will be produced. In addition, progress will be monitored against the original project plan, estimates will be refined and changes to the original specification negotiated.

A final report will be presented in which the whole product enterprise project will be critically reviewed.

6. CONDUCT OF THE ACTIVITY PROGRAMME

Clear presentation and the meeting of deadlines are essentials for success. At the end of each stage a review board, which comprises University staff and at least one industrial representative, receives written presentations and hears verbal outlines of these. The presentations are followed by an hour's discussion between each group and the Board to clarify ambiguous points and to invite the group to add missing information. Thus, before proceeding with the next stage, groups will have an agreed starting point (and may have to rethink some of their ideas).

The first two terms' work were the most novel and the most difficult. In contrast to the usual design study, students have considered, however sketchily, the problems of a marketing department faced with the task of generating a wide range of ideas and screening them in the light of market, financial and other constraints. Rather than receiving a specification to which to design something, groups have had to produce one. Whatever their future roles in industry, these students will at the least be aware that surveying a market is difficult and important and that specifications will contain ambiguities which require satisfy the customer's needs - the criterion of new product success.

7. ASSESSMENT

No attempt will be made to place individuals in an order of merit. Individual contributions to group work are continuously assessed by tutors with the aim of identifying and correcting those who are not making an adequate contribution; and final formal individual vivas are planned to decide whether any student's level of contribution and
understanding has been inadequate to justify the ultimate award of the MEng degree.

8. CASE STUDIES

About 30 of the 300 hours of the Product Enterprise programme will be devoted to case study work. A series of case studies, each with a supporting videotape, has been prepared for the course, the studies being designed to illustrate the innovation process at work in a variety of industries ranging from military communications to fruit machines. It is hoped that their study will give the impression that, though the process varies in scale and detail, all the companies studied have common problems for which a variety of solutions are possible.

9. SOME PROBLEMS

Some problems have become apparent during the first year of operation. The first shortcoming was the lack of clear-cut information about the markets and facilities of the fictitious company, about which assumptions have had to be made by tutors. Although it would be unwise to give the impression that any real company has comprehensive and risk-free market information, we believe that next year's programme will benefit from being based on a real company or companies which are prepared to co-operate by filling information gaps to the best of their ability.

A criticism often made about programmes of this type is that few university lecturers have recent industrial experience on which to base effective tutorial guidance. However, in our experience where there have been uncertainties about current industrial practice, the sponsoring companies have willingly helped to resolve them. A final problem which caused some concern in the early weeks of the programme was the apparent disorganisation of the groups and the consequent time wasted in the pursuit of pointless detail. There are now indications that groups have, of their own volition, begun to overcome this problem: this process may turn out to have been one of the most valuable learning and motivational experiences of the programme.

10. CONCLUSIONS

Although it would be rash to make firm judgements at this early stage, preliminary indications are that students are benefiting from the activity programme.

Their ability to work in groups is improving and deadlines have always been met. Written and verbal presentation of group decisions is of a standard much higher than that of most second year under-
As a result of the first stage of the programme there is a general realisation of the importance of designing to meet the needs of the market and producing products at an acceptable price, together with a realisation of the difficulty of making judgements about those needs.

The design specifications produced by students show a heartening understanding of the importance of designing for reliability and maintainability as well as for performance; and the need to work to limits of cost. As the next stage progresses they will no doubt begin to see the difficulties involved in achieving satisfactory trade-offs between these factors.

It is our firm belief that the graduates of this course will be well prepared to play effective parts in industry, whether as designers, production engineers or in marketing or sales. Whatever part they play, they will have an understanding of the many factors which contribute to the success of a new product, some of the problems involved in balancing the factors and the co-operation and communication needed for successful innovation.

REFERENCES

ABSTRACT

An undergraduate course has been established, designed to encourage students to set up companies of their own or to enter existing small consumer orientated companies. The whole course provides a study programme for the integration of the technical, economical, marketing and social aspects which are vital to the management of innovative companies. The purpose of this paper is to describe a series of exercises in which human material needs worldwide, are identified and products innovated to satisfy them.

RESUME

Un cour menant à une license a été établi, pour encourager des étudiants à former leur propre compagnies ou pour entrer dans des companies produisant des produits de consommation. La totalité du cours tournis un program d'étude pour l'integration des aspects techniques, économiques et commercials qui sont vitaux dans la direction de compagnies innovatrices. L'object de ce rapport est la discription d'une serie d'exercises ou les besoin materiaux humain dans le monde entier, sont identifiés et des produits nouveaux sont trouvés pour les satisfaire.

ZUSAMMENFASSUNG

1. THE FOUR YEAR COURSE IN ENGINEERING AND MANAGEMENT

Four years ago the U.K. Government sponsored engineering undergraduate courses of four years duration, specifically directed to manufacturing industry. The course at Birmingham has three branches within it. They are:

(a) Manufacturing Engineering, which encompasses manufacturing processes, materials and methods of manipulation, application of manufacturing systems and their constituent units, quality, reliability and economics.

(b) Design of Manufacturing Systems, in which design is treated as a system requiring optional integration of function, performance cost materials and processes.

(c) Entrepreneurial Engineering, which is described below.

2. ENTREPRENEURIAL ENGINEERING

The basic structure of the Entrepreneurial Engineering branch consists essentially of an Engineering Base in which engineering sciences, including electrical engineering computer application and mathematics are taught and a Management Base in which the elements of management such as economics, accounting, marketing, sales, industrial relations and business policy are taught. In addition two options are available: a language, which is either French, German or Russian and Business Studies, which deal with quantitative methods for running companies.

Project work, aimed at stimulating and developing innovative and entrepreneurial talents, is the subject of this paper.

3. FIRST YEAR PROJECT WORK - INNOVATION WORKSHOP (21 hours)

a. Nature of projects

A series of exercises relating to the needs of mankind, are introduced in a short talk and defined more closely on prepared sheets.

The problems range through, aids for the disabled, simple artefacts that can be made and used in underdeveloped parts of the world recycling of scrap materials, toys and games for children, domestic items and devices for use in sports and leisure activities. To emphasise the real world nature of each exercise the background and constraints to the solution are clearly defined. An example of an exercise sheet is shown in Figure 1. Three hours are allowed for each exercise and solutions are required in the form of freehand sketches in pencil, pen, black and white or colour (Figure 2). On some projects students work individually and on others, in groups of four or five persons. Oral presentations of solutions to
two projects are required. One is a group exercise, the other is the final exercise of the session, in which individuals indentify for themselves, a need in society and innovate a product to satisfy it.

b. Objectives of projects

i. Being short and numerous they help develop the habit of innovating.

ii. To provide experience of open ended non-analytical problems in contrast with the closed ended analytical ones commonly dealt with in higher education.

iii. To show that products can be innovated and the design progressed to a significant extent, without the use of advanced mathematics.

iv. To illustrate the role of engineering as a means to improving the material quality of life for mankind.

v. Their diversity helps develop the attitude that there is virtually no aspect of human endeavour to which technology has no useful contribution.

vi. Skill at communicating through freehand sketches is developed.


viii. By making the first project an exercise in designing a business
card for themselves a sense of identify as professional engineers is instilled. Also the subjects of printing and typography are introduced.

c. Role of supervisor

i. To emphasise the need for engineering innovators.

ii. To stimulate inventive attitudes and confidence in the face of inchoate ideas and immature drawings.

iii. To encourage and lead students who lack the initiative to tackle problems which have no clearly defined methods of solution.

iv. To illustrate good and bad design principles by drawing on personal experiences in professional and private life.

4. SECOND YEAR PROJECT WORK - INNOVATION WORKSHOP (30 hours)

a. Nature of projects

The exercises are of a similar nature to those of the first year, with additional attention placed on environment and the sort of usage the products are likely to experience. For example, looking mechanisms for international transportation containers, which have to locate when containers and doors are distorted through mistreatment, maintain strength and toughness in extremes of climatic temperatures, and be easily operated at all times, although devoid of lubrication, was the subject of one exercise. Another project concerned the design of an equipment transporter for SCUBA divers. In this case the sea-water environment was a major concern and also the size and weight of the transporter which had to be able to be fitted into a car-boot. A sketch of a design submitted is shown in Figure 3.

Figure 3. Concept of submarine transporter - Second year project.
Figure 4. Chair/stepladder - Design concept, materials, costs. Second year project.

Figure 5. Part of display board showing novel door lock. Second year project.
Utilising the knowledge gained from other course subjects, students are expected to consider materials and methods of manufacture in their proposals.

The second of the projects is a do-it-yourself design for a household item for which all materials used must be costed and obtainable within three miles of the campus. A convertible kitchen chair/stepladder is shown in Figure 4.

The third and final exercise requires each student to identify a need and propose a product. Ideas are justified in oral presentations to fellow students and staff.

The effort of each student is assessed according to innovative content, practically, appreciation of manufacturing requirements, communicative skills, both verbal and through the use of display boards and simple models. Figure 5 shows part of a display board illustrating a new design of door lock.

b. Objectives of projects

i. In essence the projects are designed to enable the practices of the first year to be developed further, with closer supervision and less time constraint.

ii. To examine the functioning of products in unfriendly environments and when subject to normal human misuse and abuse.

iii. To introduce materials and manufacturing requirements.

iv. To practice model making as an aid to conceptual thinking.

v. To gain experience in the use of visual aids.

vi. To obtain further practice in public speaking.

vii. To introduce experience in gathering information from commercial outlets.

c. Role of supervisor

i. To give individual advice on the practicability of products.

ii. To provide guidance on the development of ideas and the preparation of models and display boards.

5. THIRD YEAR PROJECT WORK - PRODUCT ANALYSIS AND DESIGN (36 hours)

a. Nature of projects

Students engage individually in exercises in which the design and construction of current commercial products are analysed and their performance tested.

Reports are written rating the product under the following headings: Function, Manufacture/Materials, Use, Robustness, Life, Safety, Ergonomics, Environment, Style, and proposals for redesign
are made for better performance in one or more of the above areas of for cheaper production. A verbal presentation is given by each student summarizing the findings of the reports to an audience of students, staff and members of industry. The students' efforts are assessed on sound technological analysis including the choice of experimental techniques for examining function, suggested design improvements related to function or production and standard of presentation from the point of view of verbal communication and excellence of visual aids. Figure 6 shows a section of a proposed new crash helmet design, the outcome of a project exercise.

Figure 6. New motorcycle crash helmet design.
Third year project.

6. THIRD YEAR PROJECT WORK - INNOVATION WORKSHOP (45 hours)
a. Nature of project

One exercise is tackled in which each student generates an idea, develops it on paper, and produces models or prototypes and display boards describing in some detail the function of a product for which they think there is a potential market. Using other subject material taught in the course, materials, manufacturing requirements and a market survey leading to a marketing strategy, are proposed. Assessment of each students' effort is made on the basis of an oral presentation to students, staff and invited guests from industry.
b. Objectives of projects

i. To develop abilities for critical analysis.
ii. To encourage the use of ad hoc experimentation and initiative in finding suitable items for use in tests, to assess the performance or products.
iii. To learn how to schedule a project requiring several diverse lines of action.
iv. To practice the seeking out of information (technical and legislative).
v. To learn how to make decisions on the basis of inadequate information and to use rule of thumb approximations.
vi. To gain first hand experience of market research.

c. Role of supervisor

To act as counsellor.

7. FOURTH YEAR - COMMERCIAL ENTERPRISE PROJECT (100 hours)

a. Nature of project

Groups of five or six students form 'companies' to exploit a new product which has been selected by majority decision from those suggested by each student. Each student adopts the role of a member of the executive board of directors of the company which he will be given by the 'chief executive', the person whose idea for a product is chosen. The 'company' presents its proposals verbally and in a written report, to an audience of students staff and invited industrialists, representing a source of finance for the project.

b. Objective of the projects

i. To re-introduce previous years' experiences.
ii. To gain experience of group activities.
iii. To learn the art of introducing realistic proposals in a persuasive way.

c. Role of supervisor

Advisor for all activities.
CAN 'GOING SOLO' BE TAUGHT?

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ABSTRACT

There is a growing 'demand' for more specific marketing courses from graduates of the School of Industrial Design Engineering seeking to become self-employed. Apparently, compulsory courses in Marketing, Consumer Research and Product Policy do not adequately solve attendant marketing problems. What is the real demand? A teaching/research project has been conceived with experimental courses in 1980, 1981 and 1982. The courses were freely structured to allow the students to build their own approach to fulfil specific requirements. Observation and written individual learning experiences have been analysed to define the real demand. The need appears to be different for each individual, but a freely structured course, under certain conditions, is highly motivating and effective for exploring and developing individual needs.

RESUME

Les étudiants de la Faculté de Design Industriel qui cherchent à devenir professionnels indépendants demandent des cours de marketing spécifiques. Apparemment les cours habituels de marketing, d'étude auprès des consommateurs et de la politique-produit ne suffisent pas. Quels sont leurs véritables besoins? Un projet de recherche combiné à l'enseignement a été conçu et réalisé par des cours expérimentaux en 1980, 1981 et 1982. La structure de ces cours est très ouverte pour que les étudiants puissent trouver exactement ce qu'ils cherchent. Nous avons analysé nos observations au cours du curriculum, et les récits écrits des étudiants rapportants leurs expériences personnelles et ce qu'il disent avoir appris des cours. Les étudiants ont des besoins très différents, mais, dans certaines conditions, des cours ouverts peuvent être très motivants et en plus indiqués pour explorer et développer les besoins individuels.

ZUSAMMENFASSUNG

Es lässt sich eine wachsende Nachfrage verzeichnen von Seiten der Studenten von der Fakultät für Industrielle Formgebung nach speziellen Kursen aus dem Marketingbereich, die darauf abzielen, Selbstständigkeit zu erlangen. Offenbar können die herkömmlichen Pflichtkurse für Markt- und Konsumforschung, zuzüglich für Produktplanung keine adäquaten Lösungen für
Some time ago, a Dutch journal announced a plan for the development of Small Business in the Netherlands: it proposed to send 1000 young Dutch people to Small Business Schools in the United States of America for five years, after which they would teach at Small Business Schools to be founded in Holland. This was a Large Scale approach to Small Business. I have not heard of that plan anymore.

My approach to Small Business, to become an independent, or to 'going solo', as it is called in more recent jargon, is quite different. It is a 'small scale', but highly intensive approach to 'going solo' for graduates in their last year of guided study.

It was also clearly essential to me that some entrepreneurial 'atmosphere' should be part of the course: Imagine a professor only formally teaching 'going solo' to a 'disciplined' audience preparing for an examination. My approach is therefore strongly explorative, both for the student and the teacher. It became a research/teaching project to determine what students need when they ask for specific marketing courses for 'going solo'.

This paper reports on the courses given in the spring semesters of 1980, 1981 and 1982, their structure and results. A full report on the project, containing the diaries, the learning reports of the students and detailed conclusions will be published elsewhere. (Van Eyk, 1982).

2. WHAT WAS THE PROBLEM?

Students of the School of Industrial Design Engineering of our University, wanting to become self-employed designers, had been offered certain specific marketing studies as part of an optional course for some time already. Working on that aspect more closely, I wondered why these students were asking for such a simple course having already attended quite sophisticated teachings on Marketing, Consumer Research, Product Policy and Corporate Strategy. Was it so difficult to translate this knowledge to the specific situation they were facing? Even then,
when they were shown textbooks on marketing and promotion for the design profession, still it did not become clear what they were really seeking. Further confrontation with texts on book-keeping, finance and legal aspects had a similar negative effect. All considered relevant, but.......

This vague reaction was very obvious and contrasted with the demand for 'marketing' expressed earlier. What were they really asking for? I could not distinguish 'submarkets' with any clarity. Under such circumstances I felt no stimulation to develop just a course of 'traded down' marketing notes and many financial, legal and book-keeping details that would only be valuable to them later, once they were on their own, intellectually, it wasn't much of a challenge either - not to me, nor, I felt, to the students especially.... Particularly not after the sophisticated courses they had covered already. I felt, moreover, from the many things that I would teach them in such a course, very few would be of real value to their specific requirements once they went 'solo'. Finally, I felt, these students would be able to find out all relevant items themselves, when needed, most being quite simple for their intellectual level. As students continued not to express themselves more clearly, I was still puzzled by the problem: What and how to teach; What product could I offer to meet demand?

3. THE PROJECT DESIGN

The idea on which the whole project is based is quite simple. I would offer the students, in some freely structured course, a wide variety of 'things' relating to 'small business' marketing. This way they would learn by handling and digesting the material given. Apart from being a course leader I would also be an observer of what 'happened' and, hopefully, so learn what they really need.

Although the basic idea remained, some formal aspects of this optional course had to introduced. Learning objectives and some formal structuring - albeit as free as possible - was necessary. The explorative approach, mentioned earlier, should also be included: Following years would differ from the first, each semester enriched from experiences of the preceding one. Founding an imaginary business - and going through all the phases - was one of the other solutions that crossed my mind. This, however, I found too limiting to use as the basic model.

Since 1978, I had collected many articles and textbooks on the subject. Although totalling over 10 000 pages, I judged it only marginally relevant to the students, but it was the best available at the time. As is usual, our students also expected a lot from the printed word, so I decided that the 10 000 pages should be a substantial part of the basic material to be digested. As a team they had to find their own way through it and be selective. To compensate for the mass of written words and the analytical approach, I decided to invite some small entrepreneurs/marketeers to tell, 'in person', the students about their own marketing and businesses. Apart from 'telling about', I expected that their presentation would be 'telling' too. Finally, students should write 'group' and 'individual' papers on the basis of the information
sources including, also, their learning experiences. In that way the double goals of the course would be met: Students would learn maximally from the best sources available and I would be able to observe what really matters - in this phase - in learning from marketing, whether to found one's own business or to work for a small company.

4. THE THREE COURSES

The 1980 course was set up as a workshop for 20 students that would meet once a week. Its task would be to master the available literature. There would also be lectures from guest teachers being active as small entrepreneurs. Five themes were suggested and illustrated with fragments of the available literature. The final aim was 'getting acquainted' with small scale marketing in view of becoming an entrepreneur themselves. Secondary to it was the aim to produce papers and readers that could be published and used for similar courses in the future. A schedule had been designed to ensure that the study result of each group was presented in such a way that there could be mutual integration and cross-fertilisation. It was a challenging idea to the students that there would be nothing like a textbook or a beaten path. However, after several weeks, the available literature, the teaching system and the teacher was heavily criticized and this caused a (mild) crisis. I reacted by saying not to be able, and also unwilling, to 'tell' what was the best thing to do. I only explained again the course objectives. Then the group decided to make their own decisions for finalizing the papers and the readers. From the written learning experiences and other contacts with students I learned that the formal aspects of marketing were hardly a problem. They had difficulty to 'see' marketing when it was not explicitly labelled as such. Further, much of the students' interest was focussed on the entrepreneurial personality. They particularly tried to imagine themselves in that position. The learning process and the explorative atmosphere were also doing their work; one student reported: 'How difficult it is to open up this new land'.

From these conclusions I drew up my plan for the 1981 course. As this course was quite successful, the 1982 course became a refined version of the preceeding one. To concentrate on 'learning to see' marketing in a small company and on learning to see 'myself as an entrepreneur', these courses had the following structure.

The course would start with a four weeks' study of last years' papers, including some guest teachers for some 'smell of reality'. During the next four weeks, small groups of students should visit one small company each to make a 'portrait' of the company and its entrepreneurial personalities. They should exchange these images during the workshop, allowing each student to absorb several 'reference' images of small companies. The final part would then be to reflect upon the information and images obtained, to integrate these and to relate this to oneself by placing oneself on a imaginary scale between becoming an employee or self-employed. This final part took place in a residential setting during four days and was supervised by a trainer skilled in Theme-Cent-
ered Interaction (Cohn, 1969). The use of learning experiences was also intensified. In the first year both group's and individual's learning reports were used. In the later courses only individual learning reports of a given format were accepted to give detailed feedback to me.

5. THE STUDENTS' REPORTS

I would like to return to the original question of the project: What does a student mean when he asks for specific marketing courses for 'going solo' and 'what' and 'how' shall be taught? Further, also, another question still pursues me: Can it be taught?

From the motivations that had to be written before entering the course the highest scores have gone to 'interest in (small scale) marketing' and to 'work in a small company'. 'To start own business' came in the third place. From further comments it became clear that many students that entered the course considered large companies to be bureaucratic and stifling and wanted to know more about 'small-scale-ness' either as an ideology or as an opportunity for a professional career. These motivations, however, as well the learning experiences, have to be judged within the context of the fourth year student.

The fourth year is a year of transition, which is clearly visible from their learning experiences. It is also the beginning of a confrontation with a professional career, although decisions are often delayed and avoided. This is the last year of guided study. The next year will be full time on a project in the industry. Only a few will have decided to become independent, though many feel lured by the idea: No boss around, eternal happiness in an ideal working/living environment. Yet, many prefer, after graduation, to become civil servant. This playing around with the idea of independence, not really considering it seriously, has led me to the idea of a written entrance motivation in order to exclude, at least, the most amorphous student.

There is another anomaly relevant to the situation that these fourth year students are in. The objectives of the School state clearly that the middle-size and small industries are the working field of its graduates. Yet all textbooks, not just those on management, are large company based. Although unwritten, these books imply: 'For small unsophisticated companies the rules are just the same, or should be the same'. It may be that seasoned staff have grown enough to see over this implication, but a young impressionable student is an unparalleled victim of its misleading suggestion. It obscures his view when looking at small companies.

Finally then, this year, students start to understand slowly the soaring reality that finding a job means actively searching with a real chance of not succeeding; thus definitively destroying older images. The fourth year, summing everything up, is not just a year of transition and simple confrontation with a professional career: It confronts the student with a new and uncertain professional environment.

As could be expected there is a wide variety of learning effects. The common element is that they clarify a certain relation of the stud-
ent to marketing. But how different are these relations! Quote: 'Application of marketing theory is not as difficult as it first seemed. However, we had to think of the consequences much further than before'. There is another quote about marketing and thinking. It refers to a misconception not intended by the textbooks: 'It is a misconception that marketing is for specialists. Such misconception restricts correct thinking on small scale marketing'. The next quote will rarely be found in a marketing textbook: 'The entrepreneurial personality is the most important marketing tool'.

These were quotes from the 1980 course. The learning experiences of the 1981 course are more personal. The instruction for the individual paper prescribed writing a paragraph under each of the following headings: objective learning experiences, subjective learning experiences and three concrete steps to be taken in the near future. Also in these years I find many insights that relate marketing and small scale reality. Many students develop a very personal view on 'going solo': 'you are not only to sell your ( ) product but also to put your own person in the 'weighing pans of demand and offer'. You cannot hide behind the facade of the company you work for: The company is you!'. In most learning reports, it is criticized that small scale marketing, as such, has not been taught; with some regret apparently, it would have been easier if I had 'told' them precisely what to learn. From the learning reports it becomes clearly visible that every individual has a different starting point in this process and so a different need for learning. This becomes also visible when they evaluate, for themselves, the various elements of the course. In general the information period is seen as confusing and some students suggest placing that element at the end. For others the visits to the companies and the entrepreneurial personalities were most enlightening, although some are less enthusiastic. The last part generated most of the positive remarks: 'During the residential days it becomes clear on what chair you are going to sit yourself'. But also: 'I am not conscious of having salvaged anything from the residential days'. However, his overall conclusion is: '...to me, it was a very valuable and interesting course - one that I would recommend to everybody'.

The three steps in the future worked as a moderator and a link with day-to-day reality after all the new insights. Some students are very realistic: '(I will) sell a product before August, however small it is; not something bought, but something produced by myself'. Others decide to 'profit from the advantage of being an employee', but, at the same time, discovering that you have always to be your own entrepreneur and that this means that 'applying for a job' is like 'marketing of yourself'. Still others find confirmation of existing plans: 'Continue - as never before - to look for building my own business and be more daring in placing myself in the foreground'. The new element is the 'daring', I think. Finally some students challenge the theory that you can decide for the future: 'I am using the acquired knowledge and experience from the moment I obtained them'.

This paper is too limited to give full report on the learning effect. For that reason the complete learning reports, with an analysis,
will be published elsewhere (Van Eyk, 1982). Here, I have used them as an illustration only.

6. CONCLUSIONS

Let us now return to our original questions again: The 'what-and-how' question; can it now be answered? One thing is clear: Just lecturing on small business facts and theories will be a waste of time and energy for those who want to 'go solo'. It might be different for those who seek an academic career in small business, or for those who want to study it as an ideology. This clarity, however, only shows us how not to teach it, and the question 'Can it be taught?' is also unanswered.

Yet, from the multitude of experiences during these experimental courses, a general pattern emerges. When students ask for specific marketing for 'going solo', they really believe that a course will help them with their problem. They can even be misguided by some academic 'course and examination' for earning credit points. What is really needed is different for every student and this will only come in the open when they are confronted with information, particularly with complete images of small companies and of entrepreneurial personalities to act as a (holistic) frame of reference. This sounds very much like a traditional element in engineering education: A term of probation in a factory. The difference, however, is that the confrontation in our experiment was followed by constantly repeated questions: What do you learning from it? What are you going to do with it? What do you consider important? These questions and the constant and intensive evaluation are less explicitly pursued, to say the least, during a traditional probation term.

This course also differs from traditional 'course and examination' practice, where the teacher decides what is important. Students develop a special skill to sense after a course what 'will be asked', which, therefore, is 'important'. The emerging pattern also shows us that the fourth year situation is crucial to this particular learning effect. Such a course in the first year or as a postexperience course, would work out differently.

'Going solo' can surely be learned. As an institute we can arrange for a better learning situation, as is exemplified here. Several students made decisive steps towards 'going solo' during the course. They have definitely learned. But I still hesitate to answer, confirmatively, the question: 'Can it be taught?'. This question, and also 'what' and 'how' to teach in these particular situations deserve more attention and intelligent reflection from many more disciplines than usually received. I hope that my experiments have opened up the ground for such required attention and reflection.

8. REFERENCES


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ATELIER DE CONCEPTION ET DEVELOPPEMENT DE PRODUITS

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RESUME

Concevoir et développer un produit industriel constitue un ensemble complexe d'opérations que les habitudes de penser et les pesanteurs socio-techniques françaises ont morcelé, fragmenté.

Aujourd'hui il est urgent qu'existent, dans les entreprises, des hommes responsables de cette totalité. Ils devront posséder une solide formation scientifique, être dotés d'une forte capacité de synthèse et d'un sens aigu de la portée économique et sociale de tout objet technique.

C'est à eux que s'adresse l'"Atelier de Conception et de Développement de Produits" créé par l'ESIEE.

I. Objectives générales.

Une telle formation ne doit pas imposer son rythme et ses solutions mais au contraire permettre la conception des réalités qu'elles soient techniques ou humaines, en se posant les problèmes, et non par la découverte de leurs solutions.

Elle doit donner les moyens de l'action et de la réflexion sur la matière. Elle doit offrir une nouvelle démarche propre à favoriser l'innovation, véritable course d'obstacle car elle est tributaire du milieu culturel, du cloisonnement des connaissances, de la résistance naturelle au changement.

II. Le contenu de la formation.

1. Les moyens:

Cette formation, intégrée dans la scolarité, optionnelle dès la troisième année pour l'élève ingénieur ESIEE, est axée sur la conception et le développement d'un produit proposé par l'élève ou par l'industrie.
Elle motive par un produit à réaliser et une prise de conscience globale des problèmes liés à sa conception.
Elle oriente par des apports en connaissances, en fonction des besoins (études de cas, stages intensifs spécialisés etc...).
Elle dynamise par la collaboration avec d'autres écoles d'horizon très différents et apr la participation de professionnels.

2. Le programme:

Il n'existe pas deux programmes de conception qui se ressemblent, on ne peut pas non plus instituer de hiérarchie dans
la connaissance, le caractère global d'une telle formation étant fondamental.

On peut définir 3 phases essentielles qui se retrouveront dans la plupart des cas.

a) Phase de l'élaboration de l'idée

b) Phase du développement de l'idée

c) Phase d'industrialisation.

Les enseignements:
A chaque phase sont associés des apports en connaissances pour permettre à l'étudiant d'acquérir des connaissances suffisantes pour dialoguer avec les partenaires associés dans la conception du produit. Les différents cours proposés sont:

Cours: Ergonomie

- Marketing
- Basic Design
- Analyse de la valeur
- Gestion de la production
- Norme - Qualité
- Propriété industrielle.

Séminaires: Créativité

- Méthodologie générale de la conception
- Gestion de projets
- Gestion d'entreprises.
INNOVATIVE APPROACHES IN THE TEACHING OF DEGREE LEVEL ENGINEERING DRAWINGS AND DESIGN

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ABSTRACT

After a review of the first-year B. Techn. course in 'Engineering Drawing and Design' several years ago some new teaching methods were introduced in support of the traditional approach. These new methods include an integrated approach to freehand drawing and model-making and a tutorial-based design teaching project.

Descriptions of the methods and a discussion of their development are outlined together with proposals for future work in this subject.

RESUME

Après avoir effectué, il y a quelques années, une étude des programmes de la première année de licence des études de 'conception et de dessin industriel', plusiers nouvelles méthodes d'enseignement furent introduites, en complément de la méthodologie traditionnelle. Ces nouvelles méthodes comprennent une approche intégrée du dessin à main levée et à la conception de maquettes; ainsi qu'un programme d'enseignement du dessin industriel effectué essentiellement sous forme de Travaux Dirigés.

Une description de ces méthodes, une analyse critique de leur évolution, ainsi que des propositions pour les travaux à venir dans ce domaine, sont esquissées.

ZUSAMMENFASSUNG


Beschreibungen diese Methoden und eine Diskussion über deren Entwicklung sein Vorschläge für künftige Arbeit in diesem Gegenstand sind hier kurz beschrieben.
1. INTRODUCTION

Engineering Drawing and Design constitutes a core subject in our four and five year sandwich B. Tech. courses in 'Automotive Engineering & Design' and 'Aeronautical Engineering & Design'. The course objective is to train the students to deal with the design and production process starting with basic detailed engineering drawing, appreciation of design, effective communication and leading to the final stages of product development.

In common with most engineering course subjects it has become necessary to modify and update our teaching methods to meet the new skills and technologies demanded from our graduates. This paper outlines how we have introduced new teaching methods to better prepare the students for the more effective innovative and entrepreneurial activity required by modern industry.

Before the introduction of new or modified teaching methods an assessment was made of the changing background to the subject. In this process some of the following points became apparent:

i. The course normally attracts a wide variety of ability levels; some students have done little design work whilst others have achieved a high level of proficiency coupled with some industrial experience.

ii. Most of the foreign students intake, in spite of their acceptable academic standard, come with little design background and so require greater effort at visualisation, engineering and industrial appreciation.

iii. Changing demands from industry, in particular the introduction of computer aided design and manufacture (CAD/CAM), make it less necessary for the student to acquire traditional draftsmanship skills. Graduate engineers are now expected to shoulder considerable responsibility which bears heavily on being able to convey information about basic concepts rather than detailed construction. In other words it is essential to develop their communication skills to be able to present and sell the salient, design features to colleague engineers, upper management and customers.

2. INNOVATIVE VISUALISATION TECHNIQUES

In making course changes we felt that some knowledge of graphic presentation and model-making, using up-to-date methods, should be as important to a professional engineer as it is to an Industrial designer. Despite the long tradition of technical illustration using three dimensional presentation, students applying to University engineering courses generally have little knowledge of the methods and techniques involved. It was decided that freehand drawing of engineering components would need to be included and that careful
attention should be given to the development of an engineering equivalent to the designers sketch. As the tradition of 'sketching' in general education fosters an expressive approach rather than one of clear communication it was realised that a particular style of drawing would need to be developed.

It was also decided that an ability to make effective use of colour would add greatly to the value of ideas and concepts presented. Colour poorly used can dominate and destroy effective communication and the value of colour as a supportive medium was our main concern (Baynes et al. 1978).

A natural progression from two dimensions into three has been adopted by the introduction of simple card models. Project work using models has led to demonstration of technical analysis methods and has reduced visualisation difficulties for some students.

a. Freehand drawing. For students in the early stages of freehand drawing, understanding the relationship between true shape (orthographic) and perceived shape (perspective) is a major problem (Gill 1974). This relationship is introduced by the use of simultaneous drawing and modelling exercises. A simple model is made from a given dimensioned freehand drawing (Figure 1). At the same time

![Figure 1. Simple model exercise.](image-url)
students are required to make drawings of a simple domestic object such as a three pin electrical plug (Figure 2). Thus, they experience two and three dimensional space from both points of view.

The course uses a system which enables students to construct drawings from a given viewpoint with certainty. This is achieved by imagining the component or product to be located within a transparent box constructed by using two-point perspective with long vanishing points (Gill 1975). This box-perspective establishes the spatial axes. All the centre lines normally used in orthographic drawing are retained but transferred into perceived space as co-ordinate axes. The initial drawings are lined-in and the construction system is left in position for tutorial comment. Shading is restricted to the absolute minimum; only used to convey information that cannot be represented by any other means. Lectures include freehand drawing and simple modelling, technical illustration methods, the available media for graphic presentation and the technique of colour (Porter 1980).

Towards the end of the drawing course students are given a graphic presentation project. Detailed design specifications are not required but general layouts and descriptions are requested in the form of coloured orthographic drawings and coloured perspective presentations. Students are encouraged to use a wide variety of graphic techniques according to their inclination and ability.

b. Model-making. To consolidate greater awareness of physical appearance as well as to present clearer visualisation of complex objects the students are introduced to the basic concept of 'Models in Engineering' (Stansfield 1976) in the following sequence:

i. Use of engineering models - as aids to consider ergonomics and aesthetic features, media for the communication of ideas in design, manufacture, operation and marketing, aids to teaching and to enable the assessment of the design for subsequent manufacture, assembly and performance.

ii. Scale models - scale models are considered useful, being cheaper to make, easier to modify with simpler load application and response measurements, and with visible assessment possibilities.

iii. Materials for model-making - a study is made of the available materials for model-making either for 'Qualitative Investigations' or 'Accurate Engineering Studies', depending on the property to be studied in the structure.

iv. Dimensionality - to study the conditions of similarity between a structure and a scale model and to establish a set of dimensionless ratios by means of the theory of dimensional analysis (Langhaar 1960, Pankhurst 1964).

v. Experimental methods - study of instrumentation and experimental techniques used to evaluate scale models (e.g. photoelasticity,
Figure 2. Freehand drawing exercise.
deflection measurements, photogrammetry, electrical resistance strain gauges, etc.).

The students are required to produce three dimensional, laminar card, models of engines and components from which qualitative information can be obtained. A typical exercise for a piston-conrod arrangement is shown in Figure 3.

Figure 3. Two card-board models of diesel engine conrod assembly for qualitative and simple structural assessment.

Alongside these simplified models scaled quantitative models (using conventional engineering materials are demonstrated during lectures to show the benefit of techniques leading to prototype evaluation. Figure 4a shows a half size scale model of a V8 diesel engine made of special rubber material for research studies.
Figures 4b and 4c show cardboard and wooden models, respectively, these are used for qualitative assessment only.

3. INNOVATIVE DESIGN TEACHING

In the last phase of the course, which lasts eight weeks, the student is presented with a topical design problem and guided through the design process to his preferred design. The main objectives of this phase are to illustrate the various stages in the design process, to demonstrate and produce methods of analysis and creativity stimulation, and to provide experience at solving open-ended problems. The project work also provides an opportunity for the student to apply the drawing and modelling techniques and skills developed in the earlier parts of the course.

The design problem is set in a pseudo-industrial context. The tutors act as employers (managing directors) and clients (or users) and the students have to report on their investigations to colleagues and tutors at regular intervals during the project. The students work individually and are tutored in groups of less than ten. To answer any questions of opinion or fact that are raised in the early part of the course, a meeting is arranged with the sponsor of the problem one week after the start of the project. No difficulty has been experienced with obtaining suitable problems. Over the past few years the designs have included:

**DESCRIPTION**
- Mechanical litter collection;
- Automatic grass cutting;
- Diesel engine silencing;
- Narrow truck refuse collection;
- Hover-mower safety improvements;
- Automatic fare collection;
- Improvements in car controls for the disabled;
- Rough terrain wheelchair;
- Wheelchair step climber;
- Moped for the Handicapped;
- High speed bicycle;
- Camper/tourer kit car.

**SPONSOR**
- Local authorities;
- Local authorities;
- Manufacturer;
- Manufacturer;
- Research association;
- Research association;
- User;
- User;
- Private designer;
- Private designer;
- National competition;
- National competition.

Experience has shown that at this early stage in the course it is preferable to choose broad rather than detail design problems. The format of the course is based on a general design method (Krick 1969).

At the first project meeting each student presents his version of the problem analysis in the form of a written and verbal report. The variations in emphasis and detail from students lead to group
Figure 4. a) Scale model of a V8 engine made of special rubber for accurate engineering evaluation.  
b) Card-board model of a V8 engine for qualitative assessment.  
c) Wooden model of a V8 engine for teaching and communication purposes.
discussion and illustrate the variability in interpreting design specifications. An agreed problem formulation is the outcome from the meeting and this acts as the input to the next stage.

During the second stage the students devise as many solutions to the problem as they can. They are expected to use various methods to stimulate innovation and are discouraged from detailed assessment of solutions. At the next project meeting each student in turn describes his designs until all ideas have been displayed. All the proposed solutions become 'public property' and students are expected to consider them all in the next stage. Individual reports, with drawings, brought to the second meeting and submitted for assessment ensure that students obtain credit for work done.

In the third stage students are expected to decide on the best (from their point of view) solution and produce a detailed design layout. To assist in the selection process, the main criteria for the design will have been identified at the first project meeting. A full description of the chosen design including a report, drawings and models is presented at the third project meeting. This meeting is more formal, with every student making a 'professional' presentation of his design to the group which often includes the originator of the problem. Each student is given only ten minutes to describe his design which makes preparation and planning of his presentation an important feature. As in the earlier stages, the variation in the choice and design of the 'best' solution clearly demonstrates to the students the subjective content in the design process.

The submitted reports (etc.) are used by the tutors to assess individual student ability. Initially some assessment weighting was given to the student presentations and discussion points at the project meetings, but this has now been discontinued due to the difficulty of making the assessments and the adverse effect it had on some students with regard to internal group criticism. The project meetings are now free from any form of assessment.

Several years of development in project/meeting teaching methods have shown the advantage of industrial/research involvement in the design course. Problems recently studied by professional engineers and subsequently used as design problems have the advantage that much of the necessary background work has been uncovered and is readily available. Without this the first stage of the design process is difficult to complete in the short time-scale of the course.

4. CONCLUSIONS AND FUTURE DEVELOPMENTS

Since introducing these new methods of teaching over five years ago much development of the teaching techniques and material has taken place. This is a continuing process of modification and slow improvement to reflect the changing demands placed on professional engineers. In the near future we expect to introduce several new features into the course.
At present the final model-making exercise is extended into the technical analysis area only. It should be possible to use the model to explore three-dimensional spacial relationships of form, colour and texture, thereby extending the current freehand drawing concepts. The difficulties with this development lie in the suitable choice of model exercise and the extension of material requirements and modelling techniques.

An obvious development of the methods is concerned with computer graphics. As the computer drawing facilities within the University become more widely incorporated into engineering drawing courses and as students become familiar with the use of these systems it will be possible to increase the scope of the three dimensional drawing projects to include computer simulations. The use of computer graphics for the development of visualisation skills will provide a stimulating challenge to engineering educationalists in the near future.

The U.K. government encourages the trend for closer links between universities and industry on aspects of engineering education. Collaborative research provides opportunities for further development of teaching methods. It is envisaged that current liaison with industry in sponsorship of design problems could be extended into entrepreneurial fields. Selected student designs could be taken into detail design, manufacture, sales and operation so that the complete cycle from inception to use is covered. This type of involvement currently forms part of a post-graduate design course in our University and could be modified for inclusion in the early years of the first degree courses.

As with all complex educational methods it is difficult to conduct accurate assessment on the success of the approach. The course provides a controlled exposure to the design environment, without restricting the design process, which we regard as sufficient justification for inclusion in an engineering course. Over the time the methods have been used we have had many favourable comments from industry, suggesting that these teaching methods have helped to develop graduate engineers with a good foundation for innovative and entrepreneurial activity. We are also confident that our students appreciate being faced with these challenging and often time consuming design problems. They show considerable interest in the project and recognise the value of learning new skills not covered in other parts of the course.
REFERENCES

ABSTRACT

The article deals with the foundation-phase of a business enterprise and states this to be a result of combined innovative and entrepreneurial efforts. The author recommends that technical colleges and universities shall assist and advice potential innovators on how to start up a business enterprise, in the form of running special seminars. How such a program can be accomplished is explained with reference to a seminar for engineering students who are taught relevant microeconomic topics by means of employing active training methods.

RESUME

L'article s'occupe de la fondation d'entreprises comme un accomplissement innovatoire et économique. L'auteur part du fait que les universités techniques devraient dans leur formation préparer les innovateurs à la fondation d'entreprises. Cela est démontré à l'exemple d'un séminaire pour étudiants techniques qui l'on instruit dans la matière à l'aide de méthodes d'enseignement actives.

ZUSAMMENFASSUNG

Der Beitrag befaßt sich mit der Unternehmensgründung als innovatorische und unternehmerische Leistung. Der Verfasser geht von der Überlegenheit aus, daß schon die technischen Hochschulen durch ihre Ausbildung Innovatoren auf die Gründung von Unternehmen vorbereiten sollten. Wie das geschehen kann, wird am Beispiel eines Seminars für Ingenieurstudenten beschrieben, in dem durch active Lehrmethoden vor allem betriebswirtschaftliche Kenntnisse vermittelt werden.

1. DIE PROBLEMSTELLUNG

a. Die Unternehmensgründung als innovatorische und unternehmerische Leistung

Unternehmen sind organisatorisch und rechtlich selbständige Betriebe im marktwirtschaftlichen System. Der Preis wirkt als Regulativ von Angebot und Nachfrage. Leistungsbereitschaft, Wettbewerb und Konkurrenz sowie unternehmerische Handlungsfreiheiten sind Kennzeichen der

Besteht in einer Marktwirtschaft Freiraum für eine Innovation, der von den etablierten Unternehmen nicht genutzt wird, ist die Situation für eine Unternehmensgründung günstig. Für eine Realisierung muß eine innovatorische und unternehmerische Leistung erbracht werden.

b. Der notwendige Beitrag der Hochschulen zur Ausbildung innovativer und unternehmerischer Fähigkeiten und Fertigkeiten

Unternehmensgründung ist ein Thema, das wissenschaftlich während der letzten Jahrzehnte nur stiefmütterlich behandelt wurde (Szyperski, 1980). Die Bedeutung von Unternehmensgründungen für die Regeneration einer Volkswirtschaft ist unbestritten; die Problematik wurde jedoch bisher in der volks- und betriebswirtschaftlichen Literatur eher formalistisch behandelt (Szyperski/Nathusius, 1977; Kamp et al., 1978; Schinkel/Steiner, 1980).


Einer Studie zufolge werden für 34,3 bis 47,7 % der Fachhochschulingenieur bei Berufsantritt eigens neue Stellen geschaffen (Landsberg, 1981). Offenbar modernisieren Unternehmen ihre Produktionsanlagen erst, wenn die notwendigen Ingenieure zur Verfügung stehen. Innovationen werden zurückgestellt, wenn entsprechend qualifizierte Ingenieure fehlen. Dieser Aspekt kennzeichnet z.B. Innovationsfreiräume innerhalb einer Marktwirtschaft, die partiell durch Unternehmensgründungen ausgefüllt werden können. Marktentwicklungen einschätzen zu können und Innovationschancen zu erkennen sind Fähigkeiten und Fertigkeiten, die insbesondere technische Hochschulen durch eine entsprechende Ausbildung entwickeln können. Ich bezeichne das als den notwendigen Beitrag der Hochschulen zur Ausbildung innovativer und unternehmerischer Fähigkeiten und Fertigkeiten.

2. DIE THEORETISCHE AUSBILDUNG

Wie die meisten Hochschulausbildungen ermöglichen auch die Ingenieurwissenschaften nach Studienabschluß eine selbständige Berufsausübung. Das "Route-128-Phänomen" belegt diese Behauptung (Keune/Nathusius, LERNEN WISSEN UND BILDUNG Kreativität Zufall Charaktereigenschaften Soziale Fertigkeiten Erfindung, Entdeckung Ökonomische • Systeme • Kalküle • Interdependenzen Persönlichkeit Idee einer kommerziellen Verwertung Betriebswirtschaftliche Kenntnisse Finanzierungsmöglichkeiten Transparenz des Systems Unternehmung Unternehmerische Risikofreudigkeit "Hochzeit" innovativer und unternehmerischer Fähigkeiten Exogene Einflußgrößen Abbildung 1. Das Seminar konzept: Bestimmungsrahmen einer Unternehmensgründung

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Nachfolgend beschäftige ich mich nur noch mit notwendigen betriebswirtschaftlichen Kenntnissen für eine Unternehmensgründung. Der Ingenieur als Innovator und Unternehmensgründer darf sich nicht allein vom technisch Machbaren leiten lassen, sondern hat als Raster seines Entscheidungsverhaltens ökonomische Zusammenhänge zu berücksichtigen.

Abbildung 2. Das System der Güter- und Geldströme eines Unternehmens
Er muß lernen, daß das nicht unbedingt eine Einschränkung darstellt, sondern er muß sich bemühen, sich ökonomischen Sachverstand so breit und so tief wie möglich anzueignen. Betriebswirtschaftlicher Sachverstand führt zu einer bestimmten Denkhaltung, die sich im wesentlichen auf drei Bereiche erstreckt: 1. denken im Systemzusammenhang, 2. denken in ökonomischen Kalkülen und 3. denken in Interdependenzen.

a. Das Denken im System

Durch seine Ausbildung bekommt der Ingenieur eine eigenständige Sicht und Denkhaltung, Probleme zu sehen und zu lösen. Es ist ein effizienter Ansatz, Gemeinsamkeiten technischen und betriebswirtschaftlichen Denkens herauszuarbeiten (Liebig, 1979). Das Denken im System und Sy-

b. Das Denken in ökonomischen Kalkülen

Ökonomische Kalküle gestatten es, innerhalb der Güter- und Geldströme rationale Entscheidungen zu treffen. Das Ökonomische Prinzip (Wirtschaftlichkeitsprinzip) fordert, so zu entscheiden, daß mit geringstmöglichen Mitteln ein bestmöglicher Erfolg erzielt wird (Minimalprinzip), oder, daß mit gegebenen Mitteln ein größtmöglicher Erfolg erzielt wird (Maximalprinzip). In der Betriebswirtschaftslehre werden zur Umsetzung des Ökonomischen Prinzips neben der Gewinnmaximierung (Grenzerlös = Grenzkosten) auch Modelle des Gleichgewichtsprinzips (z.B. Lagerhaltung, Materialflüsse, Finanzplanungen) und Modelle des Wirkungszusammenhangs (z.B. Wertschöpfungsgerechnung, Konkurrenz um knappe Ressourcen, Marktbeeinflussungen) benutzt.

c. Das Denken in Interdependenzen


Abbildung 3 stellt ein Branchenattraktivitäts-Geschäftsfeldstärken-Portfolio dar (Clifford et al., 1975). Es geht von folgenden Überlegungen aus: 1. je größer die Stabilität der Nachfrage am Markt, desto geringer die Umweltrisiken, 2. je größer die Flexibilität der Branche (infolge geringer Anlagenintensität und geringer Fixkostenbelastung), desto geringer die Umweltrisiken, 3. je größer die Wettbewerbsvorteile des Unternehmens (Rate der Innovation), desto geringer die Unternehmensrisiken, 4. je größer die finanzielle Stärke des Unternehmens, desto geringer die Umweltrisiken. Die Branchenattraktivität wird aus den beiden ersten Kriterien, die Position des eigenen Unternehmens aus den beiden letzten Kriterien abgeleitet.

Aus den empirischen Untersuchungen zur Unternehmensgründung kann man schließen, daß folgende Beurteilungen der o.g. vier Kriterien zum Zeitpunkt der Gründung typisch sind: 1. die Stabilität der Nachfrage ist hoch, 2. die Flexibilität der Branche ist niedrig, 3. die eigene Finanzkraft ist niedrig, 4. der eigene Wettbewerbsvorteil ist hoch (weil die Innovationsrate hoch ist). Aus dieser Analyse ergibt sich, wie aus Abbildung 3 erkennbar, das Feld 5 in der Matrix der strategischen Position. Für dieses Feld kann prima vista empfohlen werden, die
strategische Position auszubauen. Für Innovatoren kann das bedeuten: Eintritt in den Markt!

3. DIE ANWENDUNG: ZUR UMSETZUNG DER VERMITTELTEN KENNTNISSE IN BEHERRSCHTES WISSEN


Die für sinnvolle Entscheidungen erforderliche Entschlußkraft kann durch die Arbeit mit Fallstudien (Einzelstudium, Gruppenarbeit, Plendentischussion mit systematischen Ergänzungen) vermittelt werden. Die Zusammenarbeit mit den Studenten am Planspiel zur Unternehmensgründung UKS-UG 2 hat gezeigt, daß jene Fähigkeit trainiert werden kann, die eine Führungspersönlichkeit von anderen Personen unterscheidet (und Unternehmensgründer besitzen sollten): die Fähigkeit, sinnvolle und rationale Entscheidungen zu treffen.

LITERATUR

THE DEVELOPMENT OF INNOVATIVE SKILLS

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ABSTRACT

Lack of confidence in their own ability to develop new conceptual functional layout solutions instead of the existing ones is the main barrier to innovative design by Civil Engineering students. To overcome this barrier the following methods are implemented:

- Advancement of innovative thinking to the problem definition stage from the developing solutions stage.
- Students are "forced" to develop first "Ideal Solutions" based on those needs which are essential to the organisations right of existance and later, if necessary, to introduce compromises by taking into account realistic limitations (Budgets, existing buildings, equipment, etc.).
- Practicing the innovational approach in special exercises executed in factories and other institutions in Delft.

RESUME

Le manque de confiance en soi de la part des étudiants en technique civile fait obstacle à introduire des innovations qui mèneraient à de nouvelles solutions de problèmes dans le domaine du lay-out fonctionnel au lieu de maintenir les solutions existantes connues.

Pour éliminer cet obstacle les méthodes suivantes sont employées.

- Avancer la pensée innovatrice vers la phase de la définition du problème (au lieu de la restreindre à la phase du développement de la solution).
- Les étudiants sont d'abord de développer des solutions idéales basées sur les besoins essentiels et sur le but de l'entreprise et c'est seulement après que sont introduits - si nécessaire - des compromis résultant des contraintes réalistes (frais, équipement existant, bâtiments, etc).
- On fait un entraînement pratique en design innovateur dans entreprises à Delft.
ZUSAMMENFASSUNG

Mangel an Selbstvertrauen ineigenem Vermögen der Zivilingenieur-Studenten, die Erneuerungen einzufügen, welche zu neuen konzeptionellen Lösungen in funktionellen Aufbauproblemen führen könnten, statt den als bekannt existierenden Lösungen beizubehalten, ist ein Hinderniss. Um dieses Hinderniss zu beseitigen, werden die nachfolgenden Methoden angewandt.

- Vorverlegen des innovativen Denkens zur Begriffsbestimmungsphase des Problems (Statt nur in der Entwicklungs- und Lösungsphase).
- Studenten werden genötigt, zuerst Ideallösungen auf Grund der wesentlichen Bedürfnisse und Gegenstände eines Unternehmens zu entwickeln und erst dann die erforderlichen Kompromisse einzuführen, die aus den realistischen Einschränkungen hervorgehen. (Kosten, vorhandene Gebäude, Geschäftsanlagen usw.).
- In Delfter Unternehmen über die Studenten mit Innovationsprojekten in der Praxis.

1. INTRODUCTION

In the Functional Design Design Course given to students of the Dept. of Civil Engineering at the University of Delft, emphasis is put on developing the Innovative Skills of the participants. With Innovation not only improvement of existing solutions is intended. The main purpose is to encourage students to develop conceptually new solutions. It should be mentioned that Functional Design problems are complex and involve Technological, Organizational, Economical and Behavioral systems, and at the Dept. of Civil Engineering at Delft, fall under the auspices of the Civ. Eng. Management group.

To encourage human beings to consider other solutions than the comfortable reliable existing ones is not easy. Orderly creative thinking about complex problems is a very difficult occupation, although often very rewarding.

One of the main barriers to innovation which we encountered seemed superficially to be:

\textit{Lack of attraction by the challenge to create something new, instead of imitating others.}

This seemed strange. To be challenged to create something new never done before is a natural necessity for young intelligent people.

Although sometimes suppressed by years of indoctrination (from childhood), which stifles any symptoms of original creative ideas, most of the time the absence of the urge to create new solutions
results from LACK OF CONFIDENCE IN ONES OWN CREATIVE ABILITIES. 
Omitting the situations in which students really miss this 
ability, this lack of confidence results in my opinion from:

a. Lack of insight  
b. "Unknown Costs" associated with new ideas  
c. Lack of experience

Description of the methods we use to overcome the three above- 
mentioned barriers to innovative functional designing, is the main 
purpose of this paper.

2. LACK OF INSIGHT

At the beginning of the course the students are made aware of 
the fact that every new invention is only a different arrangement of 
existing and known items. In this way the importance of relations 
between things is made clear. With the aid of examples the enormous 
potential number of solutions resulting from permutations and 
combinations is understood together with the fascinating fact that 
any solution can always be improved. 

In the literature and teaching of innovation people are mainly 
encouraged in that phase of the design process where we deal with 
the HOW to solve the problem, or in other words when we try to 
develop solutions.

We have successfully tried to shift the emphasis on innovation to 
an earlier phase in the design process, where we deal with the 
WHAT has to be solved, or in other words the Problem definition 
stage.

Innovative activity during the problem definition stage 
requires some explanation.

The "end product" of the problem definition stage is a model 
which describes the factors influencing the problem and their 
mutual relations. This model can have the form of a Network, a 
Schematic Graphical or Mathematical model, or a Computer 
Algorithm (very frequently a simulation algorithm). Many times it 
develops from a Network of a system to a computer algorithm 
through different modelling hierarchies.

With these models the designer acquires INSIGHT into the 
problem to be solved, namely he:

a. Understands which factors influence the problem and how they 
influence each other.

b. Can understand and even measure the results of possible changes 
in the behaviour of factors and assumptions in regard to the 
stated problem (Sensitivity tests).
c. Creates tools to evaluate and compare new designs.

This short paper only allows me to outline the process we suggest to our students for reaching the final problem definition.

a. Stating the "initial Aim", (Which seldom is the "Final Aim").

b. Orientation with the existing situation.

c. Determination of Criteria (Requirements, Needs, Demands, Desires and Wishes), which the solution has to fulfill.

d. Determining the factors which are influencing the different Criteria.

e. Determining the intensity and direction of the influences.

f. Determining which factors and how they have mutual relations.

g. Creating an Algorithm (and often a Computer Program) for simulating new alternatives.

A lot of creativity and imaginations is needed to create the tools to enable a designer to understand complex and entangled systems (which most civil engineering designs are about). The young men in their final stage of study have often much more confidence in their theoretical background knowledge in the sciences of Mathematics Physics, Mechanics, etc. than in their ability to change existing solutions. Not knowing that innovations are often not only a result of designing experience, but of a different understanding of the needs and the factors influencing the needs.

It is always fascinating when students discover their ability to use their analytical tools to acquire insight and understanding of not only purely Technical Problems.

When they discover that they are contributing to new and appreciated approaches to the problem, the "Ice is Broken" and their confidence in their abilities to innovate grows.

3. UNKNOWN COSTS ASSOCIATED WITH NEW IDEAS

Most young designers associate existing solutions with optimal costs and proven reliability.

This causes an interesting Paradox. The striving to optimization (costs) creates a mental block for the development of new (associated with high unknown costs) solutions.

Not only designers, but also employers (and teachers) like to "associate" their orders for a design with limitations imposed by the existing situation. DECLARATIONS like: Existing Buildings, Equipment, Processes, Information systems, Policies, Instructions,
Organizational structure, plot boundaries and budgets have to be preserved are frequently inflicted, often as very realistic and justified instructions. Nevertheless these kinds of declarations are real "innovation killers" for the young designers (and not only for the young ones) as they drastically narrow the range of possible solutions.

To overcome this problem students are made aware of the difference between needs which are derived from the main purposes of the organization and are its justification of existence and requirements which are originated in human minds as a result of incidental circumstances, let us call them limitations.

The usual method to develop solutions is the following:

Although the results of this method will usually only include slight improvements of the existing situation, it has its value by creating alternative designs which are important in our comparison systems.

In addition to the above method the students are "forced" to use the following method:

This method results in new conceptual solutions. Barriers of limitations and money are removed during the first stage of developing the Ideal Solution. Only then limitations are introduced and the necessary compromises in regard to the ideal solution are made. The final design is different (much more conceptual changes) than from the designs arrived by the usual method.

Explanation of the term ideal solution seems desirable. With ideal, the maximalisation of "under control degree is meant, or in other words minimalisation of deviations from fulfillment of needs (also under changing conditions) is being striven for.
Instead of using COSTS as reference, in this stage fulfillment of main needs is the measure.

Several means for increasing the degree of control are introduced for example:

- Execution in stages (Designing in phases from masterplan to immediately executed detailed design).

- Elimination of deviations by elimination of factors which are the cause to the deviations.

- Built-in flexibility. (The installation can accept changes without being calculated for overcapacity).

- Built-in regulating equipment (deviation from fulfillment of need activates a correction device, thus AUTOMATION).

Instruction time and examples are especially dedicated to AUTOMATION as a means to increase the Manageability of designs. (Manageability is just another term for Degree of Control.) AUTOMATION is introduced as a Management Philosophy and not only as a mechanical device.

The Ideal Solutions are confronted with the Limitations and Compromises take place. Often certain limitations are omitted when management realizes that the damage caused by taking them into account is greater than the supposed savings.

In the final design stage the feasibility of the different solutions and their qualitative properties are analysed in a way that encourages further innovations (Thus not only in a comparing and eliminating process).

4. LACK OF EXPERIENCE

During the instructions the students have "absorbed" the importance of innovation during all the design stages, from stating the problem, collection of data, developing solutions and the final choice between them. Many aids and examples are shown, but to learn to innovate students need Practice.

To achieve practice the final examination is combined with an exercise executed in factories and other enterprises in Delft and its surroundings. The students are divided into small groups of about four persons. Every group gets a design task which is chosen in consultation with management and considering their wishes. The tasks are of an multidisciplinary character. Although the final design is expressed in dimensions (drawings) great importance is given to the way the solution is derived at and works. In the final design of a storeroom for example, integration between Storage, Material Handling and Information Systems, Human Safety and Satisfaction, Optimal Inventory etc. are brought
into consideration. Instructors pay special attention to the manner of developing the Ideal Solution and how it is fitted to the existing conditions in a realistic design. In general Management is surprised and appreciates the students' ability to develop solutions totally different from the existing ones in a relatively short time and without previous knowledge of the problems.

REFERENCES
ABSTRACT

Since 1973 the Universities of the Armed Forces of the Federal Republic of Germany in Hamburg and Munich have offered a remarkably successful three-year programme of studies. Their purpose is to offer to career officers and those with long commissions a recognised university degree (diploma) course which must be completed in at the most 4 years. For this reason the programme of studies is governed by 3 basic demands: (1) studies limited to 3 years divided into trimesters, (2) the equivalence of degrees (diplomas) with those of state universities, and (3) a reasonable success quota. The first two conditions lead to a very full and compact curriculum that necessitates very great efforts in order to satisfy the third goal. The aerospace engineering course will serve as an example of how in little more than 3 years engineering students are equipped with a broad knowledge of basics and specialised knowledge of one particular field.

RESUME

Depuis 1973 on étudie avec beaucoup de succès dans les universités des Forces Armées de la République Fédérale d'Allemagne à Hambourget à Munich. La durée réglementaire des études est de 3 ans. La mission de ces universités est d'offrir aux officiers des études universitaires leur permettant d'obtenir en 4 ans au maximum des diplômes reconnus par le ministère des affaires culturelles et qui, en conséquence, rendent des diplômes aptes à l'exercice d'une profession civile. Pour cette raison ces études sont déterminées par 3 exigences: (1) Études en trimestres; la durée réglementaire de ces études est de 3 ans. (2) Diplômes équivalents à ceux des universités fédérales. (3) Honorable pourcentage de réussite.

Le cours des études à la faculté aéronautique et astronautique servira d'exemple pour démontrer comment les étudiants acquièrent, en peu plus de 3 ans, un large éventail de connaissances.

ZUSAMMENFASSUNG

Seit 1973 wird an den Hochschulen der Bundeswehr in Hamburg und München in dreijähriger Regelstudienzeit mit bemerkenswertem Erfolg
studiert. Diese Hochschulen haben die Aufgabe, längerdienenden Zeit­
offizieren und Berufs­offizieren ein universitäres Studium anzubie­
ten, das in höchstens 4 Jahren zu staatlich anerkannten und damit
zivil­berufs­befähigenden Diplomen führt. Deshalb wird das Studium von
drei wesentlichen Forderungen bestimmt: (1) dreijährige Regelstu­
dienzeit im Trimesterrhythmus, (2) Gleichwertigkeit der Abschlüsse
mit entsprechenden Diplomen von Landesuniversitäten und (3) eine er­
trägliche Studienerfolgsquote. Die beiden ersten Vorgaben führen zu
einer hohen curricularen Verdichtung, die außerordentliche Anstren­
gungen nötig machte, damit das dritte Ziel erreicht werden konnte.
Am Beispiel des Studiengangs Luft- und Raumfahrttechnik wird ge­
zeigt, wie ingenieurwissenschaftlichen Studenten in wenig mehr als
drei Jahren ein breites Grundlagenwissen und spezielle Kenntnisse
aus einem Schwerpunkt vermittelt werden.

1. DIE WURZELN DES KONZEPTES

Die annähernd gleichzeitige Behandlung der Hochschul- und der
Streitkräfte­reform in den frühen 70er Jahren hat wesentlich beigetra­
gen zur Konzipierung von Hochschulen der Bundeswehr, an denen
seit 1973 in dreijähriger Regelstudienzeit studiert wird.

a. Hochschulreform

"Bildung und Ausbildung, Wissenschaft und Forschung stehen an der
Spitze der Reformen, die es bei uns vorzunehmen gilt", hatte Willy
Brandt in seiner Regierungserklärung vom 28.10.1969 betont. Wenig
später legte der Bundeskanzler (08.06.1970) seinen "Bericht zur Bil­
dungspolitik" vor, "der aus einer Beschreibung und Analyse der ge­
sellschafts­ und bildungspolitischen Wechselwirkungen ... - unter
Berücksichtigung der Empfehlungen der Bildungskommission des deut­
schen Bildungsrates (Feb. 1970) und des Wissenschaftsrates (Okt.
1970) - bildungspolitische Zielvorstellungen entwickelt."

Einleitend werden die vom fundamentalen Recht auf Bildung abge­
leiteten Grundsätze für die Reform des gesamten Bildungswesens der
Bundesrepublik Deutschland genannt. Für den Hochschulbereich stimmen
die Reformvorstellungen weitgehend mit den Empfehlungen des Wissen­
schaftsrates überein.

Die angestrebte organisatorische und quantitative Neugestaltung
wollte die Bundesregierung durch die Bildung von Gesamthochschulen
und die Verdopplung der Kapazität des Hochschulbereichs im Laufe von
zehn Jahren erreichen. Ergänzend erklärte sie hierzu: "Die organisatori­
schen Ausbau- und Reformmaßnahmen dienen dem eigentlichen Ziel
aller Bemühungen: der inneren Hochschulreform, die in Lehre und For­
schung, Selbstverwaltung und Kontrolle, Planung und Ausbau den Er­
fordernissen der Zeit ... gerecht werden soll."

Aus diesen Zielvorstellungen wurden zahlreiche Reformmaßnahmen
abgeleitet. Hier können nur einige Aspekte zur "Reform des Studien­
systems" (S. 68) genannt werden: "Das Studium muß neben dem Fachwis­
sen und den fachbezogenen wissenschaftlichen Methoden vor allem die
Die Fähigkeit zu selbständig kritischer Wissenserweiterung zum Erkennen und zum Lösen neuer Probleme vermitteln. Diese inhaltliche Ausgestaltung ist wichtiger als die Dauer des Studiums. Kein Studienabschluß kann – auch nach noch so langer Studiendauer – eine für das gesamte Berufsleben ausreichende Fach- und Methodenkenntnis bereitstellen: so gesehen ist jeder Abschluß zugleich ein Abbruch ... Jedes Studium muß vielmehr auf die Möglichkeit ... des Weiter- und Ergänzungsstudiums angelegt sein ... Im Rahmen der Hochschulgesetzgebung wird die Bundesregierung prüfen, ob die derzeitige Semestererteilung durch das Studienjahr ersetzt werden soll ..."

b. Streitkräftereform

Ende der 60er Jahre war die Bundeswehr in eine komplexe Krisegarten, die nicht nur die Planung und Führung sowie den Rüstungssektor betraf, sondern ebenso gravierend auch die Wehrstruktur, den Personalbereich und das Ausbildungswesen. Als ersten Schritt zu ihrer Überwindung kündigte die Bundesregierung am 28.10.1969 eine "kritische Bestandsaufnahme" an. Ihre Ergebnisse legte sie im "Weißbuch 1970" vor, das über einen Bericht weit hinausgeht: es "ist das sicherheitspolitische [Reform-]Programm der Bundesregierung für die nächsten Jahre."


2. KONZEPT UND REALISIERUNG

a. Das neue Modell der Offizierausbildung

In ihrem Gutachten vom 6.6.1971 empfiehlt die von Prof. Th. Ellwein geleitete Bildungskommission das folgende "Ausbildungsmodell:

(1) Offizieranwärter, die sich für eine Dienstzeit von 12 Jahren verpflichtet haben oder Berufsoffizier werden wollen, durchlaufen eine 5jährige Ausbildungsstufe.

(2) Sie besteht aus 2 Jahren militärischer Ausbildung und einem 3-jährigen wissenschaftlichen Studium. Trotz dieser Zweiteilung ist sie als eine Einheit zu verstehen ... Deshalb sollen nur solche Fachbereiche angeboten werden, die für die Tätigkeit des Offiziers von Nutzen sind ..." (Gutachten, Ziffer 49).

Diese Zeiteinteilung wurde als die optimale Abstimmung von Dienstzeitlänge (12 Jahre), Dauer der grundlegenden militärischen Ausbildung (2 Jahre) und Studiendauer (damals 3,0 Jahre) angesehen unter Berücksichtigung des für den Truppendienst notwendigerweise geringen Alters des Zeitoffiziers ("twen") und des am zivilen Arbeitsmarkt bei Akademikern üblichen Höchstalters für den Wechsel in einen anderen "Betrieb" (32 Jahre).

b. Hochschulen der Bundeswehr

Die Bildungskommission schlug aus verschiedenen Gründen vor, den wissenschaftlichen Teil der Offizierausbildung an eigenen Hochschulen der Bundeswehr durchzuführen. Für diese geht sie u.a. "von folgenden Grundsätzen aus:


Das Studium muß so geordnet sein, daß in der Regel eine Dauer von 3 Jahren nicht überschritten ... wird.

Militärische Ausbildung und Studium gehören zusammen ... Zwischen den allgemeinen Hochschulen und den Hochschulen der Bundeswehr ist eine enge Kooperation anzustreben." (Gutachten, Ziffer 57).


3. LEHRE UND STUDIUM AN DEN HOCHSCHULEN DER BUNDESGERICHTSHAFT

Die Hochschulen der Bundeswehr führen die universitären Studiengänge Bauingenieurwesen (M), Elektrotechnik (H + M), Informatik (M), Luft- und Raumfahrttechnik (M), Maschinenbau (H) und Vermessungswesen...
sen (M) sowie Pädagogik (H + M) und Wirtschafts- und Organisations-
wisssenschaften (H + M). Dafür stehen in Hamburg (H) und München (M)
jeweils etwa 2.000 Studienplätze zur Verfügung. Beide Hochschulen
besitzen das Promotions- und Habilitationsrecht.

a. Gleichwertigkeit und Studienerfolgsquote

Das - gemessen an Landesuniversitäten - gleichwertige, aber nicht
gleichartige Studium ist so geordnet, daß es frühsten nach 3 1/4,
spätestens nach 4 Jahren abgeschlossen werden kann. Dabei ist das
Studienjahr in 3monatige Trimester und eine vorlesungsfreie Zeit
von ebenfalls 13 Wochen eingeteilt. Das 10. Trimester ist lehrver-
anstaltungsfrei; es dient der Bearbeitung der Diplomarbeit und der
Prüfungsvorbereitung. Da ein Teil der berufspraktischen Tätigkeit
den vorlesungsfreien Zeiten abgeleistet wird, entspricht der Min-
deststudienzeit von 3 1/4 Jahren eine Regelstudienzeit von 3 Jahren.

Das Trimester ist mit netto 12 Wochen um etwa 15 % kürzer als ein
durchschnittliches Semester. Geht man von durchschnittlich 27 Trime-
sterwochenstunden aus, so können im Laufe eines 9trimestrigen Stu-
diums insgesamt 27 x 12 x 9 = 2.916 Stunden Lehrveranstaltungen ge-
halten werden. Mit der besseren Ausnutzung des Studienjahres alleine
war jedoch das zentrale curriculare Problem - die Verbindung von
Gleichwertigkeit und Dreijahresrhythmus - nicht zu lösen. Dies ge-
lang erst durch weitere Maßnahmen wie
- Stoffreduktion bezogen auf die Lehrpläne von Landesuniversitäten,
- optimal strukturierte Studienablaufpläne,
- inhaltliche Abstimmung der Lehrveranstaltungen bei weitgehender
  Vermeidung von Redundanz,
- intensive Lehre in sehr kleinen Gruppen,
- umfassende Studienberatung.

Fig. 1. Input-output-Studienerfolgsquote

der Immatrikulationsjahrgänge 1973 bis
1977 im Studiengang
- Bauingenieurwesen (BAU, 42),
- Vermessungswesen (V, 35),
- Elektrotechnik (ET, 183),
- Informatik (INF, 89),
- Luft- und Raumfahrttechnik (LRT, 119),
- Pädagogik (PÄD, 75),
- Wirtschafts- und Organisationswissen-
schaften (WOW, 108)
der Hochschule der Bundeswehr München;
bemerkenswert ist die zunehmende Konver-
gens auf den Mittelwert der Hochschule
(∅, 65%) In Klammern: Kurzbezeichnung,
Studenten-Sollsahl pro Immatrikulations-
jahrgang.
Die (als Verhältnis von Jahrgangsstärke bei der Immatriculation zu Zahl der Diplomierungen definierte) input-output-Studienerfolgsquote der Hochschulen der Bundeswehr (Fig. 1) liegt zwar etwas unter den Werten von Landesuniversitäten; sie braucht aber einen Vergleich, der die dreijährige Regelstudienzeit als "Handikap" bewertet, nicht zu scheuen. Ähnliches gilt für den Abschluß-Notenspiegel.

b. Als Beispiel: das Studium der Luft- und Raumfahrttechnik

Fig. 2 zeigt den Studienablaufplan des Studiengangs Luft- und Raumfahrttechnik, jedoch ohne die Studienarbeit und die Diplomarbeit, für die 3 bzw. 6 Monate vorgesehen sind. Jeder "Balken" repräsentiert ein Trimester (Trim.), dessen Gesamtbetrag in Trimesterwochenstunden (TWS) rechts in einem Dreieck angegeben ist. Die für die einzelnen Fächer vorgesehene Stundenzahl kann an der TWS-Skala abgelesen werden; darüber hinaus ist sie zahlenmäßig nach der Lehrveranstaltungsform aufgeschlüsselt (z.B. V3 = 3 TWS Vorlesung).

Die Lehrveranstaltungen des Fachstudiums (Fig. 2) werden ergänzt durch erziehungs- und gesellschaftswissenschaftliche Anteile des (Gesamt-)Studiums im obligatorischen Umfang von 2 TWS pro Trimester. Daher beträgt die durchschnittliche Studienbelastung 27 TWS.

Das Fachstudium gliedert sich in ein 3trimestriges Grundstudium und ein 6trimestriges Hauptstudium. Im Grundstudium, das mit der Diplomvorsprüfung (vgl. Ulbricht und Zimmermann, 1979/80) abgeschlossen wird, sind Lehrveranstaltungen im Umfang von 84 TWS zu absolvieren.


Fig. 2. Studienablaufplan des Studienganges Luft- und Raumfahrttechnik der Hochschule der Bundeswehr München.

Abkürzungen: V = Vorlesung, WV = Wahlpflichtvorlesung, U = Übung, SU = Seminarübung, S = Seminar, P = Praktikum, AP = Apparatives Praktikum
Vielmehr soll sie dem Studenten exemplarisch und entsprechend seinen Neigungen ermöglichen, seine Kenntnisse auf einem typischen Gebiet der Luft- und Raumfahrttechnik zu vertiefen.


c. Weiterbildung

Die Absolventen der Hochschulen der Bundeswehr, die ab 1984 die Bundeswehr als Zeitoffiziere nach 12 Jahren Dienst verlassen werden, sind in der Truppe zum Teil nicht so verwendet worden, daß sie ihr Studium fachlich nutzen konnten. Beim Eintritt in das zivile Berufsleben wäre ihr Studium also um etwa 7 Jahre "veraltet". Daraus ergibt sich die Notwendigkeit einer Auffrischung.


Abschließend danke ich Herrn Hauptmann Richter, S 1 Offizier im Stab des Studentenbereichs der Hochschule der Bundeswehr München, für die Mitteilung der Studienerfolgsquoten, die in Fig. 1 graphisch dargestellt sind.

LITERATUR

Bayerisches Staatsministerium für Unterricht und Kultus:

Bildungskommission beim Bundesminister der Verteidigung (6.6.1971):
Neuordnung der Ausbildung und Bildung in der Bundeswehr. Bonn.


Weißbuch 1970 Zur Sicherheit der Bundesrepublik Deutschland und zur Lage der Bundeswehr. (Bundesminister der Verteidigung, ed.). Bonn.


This should be one of the most important sessions of the Conference because the papers will be presented by people who are actually practising the innovation of products and processes against an educational background.

Case studies of successful innovation present the engineering student with the real-life situations which convey innovative ideas through the research, design and development stages to essential commercial aspects such as the marketing of new products and producing them industrially with control of quality and economic considerations of both cost and time. Examples can be taken from actual industrial practise so that the decisions made at all levels of professional practise can be reviewed with hindsight. Such procedures have rarely been used in engineering education, although they are regularly practised in other disciplines such as medicine, law and business management.

The paper by my colleagues and I illustrate how undergraduate students at Loughborough University of Technology have actively participated at various stages in the innovation of commercially viable textile machinery. From some 30 typical cases of academic-industrial collaboration, two have been spotlighted for discussion. The first shows how a company commissioned us to design and build prototype machinery based on previous research at the University and how this has been initiated through and fed back into both design teaching and projects undertaken by students. The second shows how a University generated-idea achieved worldwide commercial success with an industrial company and yet this started its life through final year undergraduate student projects. In both of them the industrial aspects of the innovative and entrepreneurial activities have therefore been effectively conveyed through the education process.

A joint paper from Sunderland Polytechnic and Queen Mary College, London, illustrates how a novel anchoring system was developed for the offshore industry by establishing a small university-based company whereby technical investigations and developments were linked with commercial considerations such as product protection, licensing and marketing. The relevance to engineering education is discussed and a number of difficulties inherent in such an operation are highlighted.

The detailed study of an industrial product, a power tool, has formed the basis for a product design study at the University of
Reading, whereby the designer of the product has discussed with the students his company's marketing policy and its approach to value engineering, manufacture and cost.

A special laboratory for process equipment has been established at the Delft University of Technology, which enables the marketing and economic aspects of engineering product development, as well as research and development activities, to be linked to the education of students.

At Napier College a course specifically dealing with innovation and entrepreneurship has been devised in which case study material is incorporated to show unsuccessful as well as successful ventures.

The inherent difficulties and lessons learned from bringing case studies into teaching is highlighted by design project experience at the University of Detroit. Such case studies have involved sub-divisions of engineering and have raised questions of human behaviour and ethics as well as being concerned with technical matters.

The wide variety of case studies to be presented in this session should therefore provide the basis for much useful discussion. The following questions might usefully be considered:

1. What is innovation? What is entrepreneurship? What are the conditions for cooperation of an academic institution with an existing industrial company? What are the circumstances whereby entrepreneurial activity, e.g. to the point of forming new companies, might be demanded from the academic institution for the development of a university-inspired innovation?

2. How can innovation and entrepreneurship be conveyed to engineering students? Can it be 'taught' or is it to be 'caught'? Should the students and academic staff be directly involved in the actual innovation of new products and processes?

3. What are the values of case studies in engineering education? Should they be taught by people who have experienced innovation and entrepreneurship at 'first-hand', or is it possible to teach them 'second-hand', i.e. based on other people's experiences?

4. From the particular case studies presented in this session what can be learned regarding the education of the engineer for innovative and entrepreneurial activity? Has there been a common theme to the different experiences described in the various papers?

5. Should a distinction continue to be made between the conventional teaching of fundamental subjects such as mathematics, mechanics, fluid dynamics, etc. and the application of these fundamentals in engineering? Are there other ways than case studies for educating the student engineer towards the real needs of industry for new and improved products and processes?
RESUME

Afin que ceux qui font des études d'ingénieur puissent comprendre les facteurs qui influencent les procédés innovateurs dans l'industrie, et aussi pour qu'on aide ces étudiants à développer leurs talents d'entreprendre, il est nécessaire qu'ils possèdent des connaissances de l'effet des changements technologiques sur des industries diverses, autant que sur des compagnies individuelles: ces connaissances doivent être liées avec une connaissance du rôle du gouvernement et de ses attitudes envers l'avancement des changements technologiques.

La co-operation étroite avec deux groupes - celui des économistes et des ingénieurs de production qui collaborent avec les ingénieurs dans les industries associées à ces procédés innovateurs et celui des entrepreneurs prospères - a permis au personnel enseignant de Napier College d'introduire, dans la licence révisée pour la Technologie et les Études Industrielles un cours qui traite de l'innovation et des fonctions d'entreprendre.

Notre communication aura pour but la description du cours et l'exposition en détail de la documentation des études faites pour le cours, y compris le développement infructueux des machines-outils MC chez Ferranti, les tentatives réussies par des compagnies écossaises dans l'industrie aérospatiale et dans la technologie pétrolière dans la mer du Nord, et les efforts d'entrepreneur faits par les ingénieurs dans l'électrotechnique et la mécanique pour établir de nouvelles compagnies prospères.

ZUSAMMENFASSUNG

Um den Studenten des Ingenieurswesens Einsicht in die den industriellen Innovationsprozess bestimmenden Faktoren zu geben und die Entwicklung ihrer unternehmerischen Fähigkeiten zu fördern, ist es notwendig, dass sie über die Auswirkungen technologischer Veränderungen in verschiedenen Industriezweigen und bei einzelnen Unternehmen informiert sind; darüber hinaus sollten sie über Kenntnisse der Rolle der Regierung und deren Haltung gegenüber der Förderung des technologischen Fortschritts verfügen.

Aufgrund der engen Zusammenarbeit zwischen Volkswirtschaftlern und Produktionsingenieuren des Kollegiums des Napier College
einerseits und Ingenieuren, die sich mit dem Innovationsprozess bei Industriebetrieben befassen, und erfolgreichen Unternehmern andererseits ist der Lehrkörper des Napier College in der Lage, mit dem überarbeiteten Technology and Industrial Studies Degree einen auf Innovation und Unternehmungsinn einen gerichteten Kursus einzuführen.

Die Abhandlung beschreibt den Kursus und untersucht ausführlich das darin enthaltene Fall studienmaterial, das u.a. folgendes behandelt: die misslungene Entwicklung der MC-Werkzeugmaschinen bei Ferranti, der gelungene Einsteig schottischer Unternehmen in die Luftraum- und NordseeÖltechnologie, das unternehmerische Wirken von Maschinenbau- und Elektroingenieuren bei der Gründung von erfolgreichen, neuen Gesellschaften.

The success of companies in manufacturing industry depends on their ability to successfully develop goods which can be sold in the market at competitive prices and on the quality, reliability and safe operation of these goods in service.

However, for a company to survive and develop the engineering activities must be supported by adequate infusions of cash at the correct time to enable the company to successfully innovate and develop their products, purchase additional plant and capital equipment, pay the wage bill of the employees and make sufficient profits for new investments and to pay a dividend to the shareholders of the company. It is also essential that the company develops an organisational structure which is sensitive to changes in its external environment and which can respond to these external changes. This is achieved for many companies by the establishment of 'organic' types of team groupings where much attention is devoted to mixed discipline project teams.

The Finniston Committee of Inquiry into the Engineering Profession in the United Kingdom identified the need for engineers to find themselves taking part in and responding to a more participative process of change, through joint discussion of their work and its impact and effects at many levels with workers and their representatives as well as with fellow engineers and managers. This wider role will require that engineers develop appropriate skills in the following areas:

- the ability to express and communicate both verbally and in writing
- managing and participating in meetings in which engineering expertise is one of the elements contributing to decisions and
- mastery of cost and budget information.

The Finniston Committee stated that it was their impression (backed by evidence gained from overseas visits) that engineers in other countries such as Sweden, Japan and the USA are better prepared to operate effectively in these broader areas within the engineering dimension than their British counterparts.

It is considered by staff at Napier College that the education of the engineering undergraduate should in addition to the studies of mathematical and engineering sciences, production engineering and
applied technologies should include studies of organisation theories, financial studies and a course which encompasses the decision making and taking process in business. These latter studies will provide the undergraduate engineer with a knowledge of how firms select which projects are developed and which discarded, how forecasts are made of sales and profits and how cash flow and the life of a project are predicted.

The education of the undergraduate should also include an understanding of the control systems which are required to provide engineering managers and other specialists with the necessary information to successfully monitor performance, to anticipate trouble and permit successful corrective action to be taken. The role of electronic data processing is emphasised since many companies now have integrated engineering/financial information systems.

These studies have been designed by an interdisciplinary team of production engineers, economists, accountants and managers supplemented by practising industrialists to provide the student with a knowledge of the principal factors which influence the successful development of new products and which have permitted some companies to grow and develop whilst others have failed.

During these studies, much of which are based on factual case studies, considerable emphasis is placed on the entrepreneurial aspects of engineering management. The role of the entrepreneur has been defined as being characterised by a style developed out of a search for opportunities in the environment and one which is also capable of organising resources to overcome challenging ventures out of which he draws high levels of personal satisfaction. The attention of the student is drawn to the fact that entrepreneurial activities exist not only in small companies but that many large companies, particularly those involved in advanced technology, have organisational structures which encourage individual managers to assume the role of the entrepreneur.

The case studies used to indicate the success and failure of the entrepreneurial activity include the following:

The development by Messrs Ferranti Ltd of a range of numerically controlled machine tools designed to meet the needs of the aerospace industry for machines to manufacture complex shapes. The difficulties faced by Messrs Ferranti as a market leader are considered, the reasons for deciding on a magnetic tape system with centralised processing facilities as opposed to paper tape are considered together with the large sums expended on research and development all illustrate the reasons for the almost inevitable failure of the venture. The alternative strategies adopted by successful companies are considered.

Other case studies based on the successful development of two local companies illustrate the ability of individual engineers to use their entrepreneurial skills to establish small companies which are able to compete effectively against larger companies. In both cases the companies concerned have provided access to a
range of engineering and financial information which gives students a valuable insight into the way these companies can provide closer contact with customers, exploit opportunities which the larger companies have failed to exploit and also the ease with which certain markets can be entered.
The studies illustrate how at times when the economy is expanding the very complex interrelationship between technological change and market growth afford the opportunity for new and small companies to be created.
The discovery of oil under the North Sea has led to considerable engineering activities in the exploitation and development of these oil reserves. In general Scottish companies have failed to profit from these activities. However some companies have been very successful and one of these had been founded by a former member of College staff and the problems which have had to be overcome in breaking into this new technological field have formed the basis of a most interesting study.
Students are encouraged to analyse the reason why Scottish companies have failed to gain entry into what appears to be potentially lucrative markets.
The final years of the degree also includes interactive management games designed specifically for this course by members of College staff. These have been designed to illustrate the entrepreneurial and managerial skills required by practising industrial managers with emphasis on the need to carefully formulate policies prior to making decisions.
This course had been designed prior to the publication of the report of the Finniston Committee and has anticipated many of its recommendations. It is the hope of the team who designed the course that by allowing the undergraduates to meet and discuss with engineers who are responsible for the development of their own companies some of them will be encouraged to consider establishing their own company after gaining suitable industrial experience.
UNIVERSITY/INDUSTRY COLLABORATIVE TEACHING

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ABSTRACT

Design must be taught in the context of real life engineering and must be seen to be the vital ingredient, the common factor, that brings all engineering disciplines together in the correct balance which reveals the underlying economic priorities.

The paper describes a collaborative venture between Reading University and Black & Decker in which a product, marketed world-wide, is used in a design project to stimulate in the minds of engineering undergraduates the vital ingredients of successful product design.

It is too easy to concentrate on the innovative and analytical aspects of design omitting commercial considerations such as marketability and compromises between quality, cost and time. To concentrate more on these commercial factors we have moved from the standard type of project, in the early part of our degrees, to a more industrially orientated design exercise involving the detailed study of a product with the active participation of the designer.

RESUME

Le 'design' doit être enseigné aux ingénieurs dans un contexte rapporté à la vie réelle et doit être aperçu comme l'ingredient principal, le facteur commun qui, réunissant toutes les disciplines des études d'ingénieur dans un ensemble harmonique, révèle les priorités économiques de base.

Cette communication décrit une entreprise de collaboration entre l'Université de Reading et Black & Decker pendant laquelle un produit industriel, mis aux marchés de tout le monde, a été utilisé pour un projet de 'design' afin de stimuler les élèves de l'école d'ingénieurs à penser aux ingrédients essentiels pour la réussite du 'design' d'un produit. Il est trop facile de se concentrer sur les aspects innovatifs et analytiques du 'design', laissant de côté considérations commerciales comme la mise au marché et les compromis entre qualité, coût et temps.

ZUSAMMENFASSUNG

Ein Plan muss im Enthalt der tatsächlichen Ingenieurkunst gelernt
sein und muss als das wichtigste Bestandteil gesehen sein, der gemeinsame Factor welcher alle ingenieur Belehrungen in der gerechten Gleiche zusammen bringt, und auch die unterliegenden ökonomischen Vorzugsrechte erzeigt. Das Blatt beschreibt eine kombinierte Unternehmung zwischen Reading Universität und Black & Decker in welcher ein Erzeugnis, welches in der ganzen Welt erkaufl ich ist, als plan Entwurf benutzt wird, um den Gedanken der ingenieur Studenten zu den wichtigen Bestandteil eines erfolgreichen Erzeugnis zu reizen. Es wäre zu einfach das man sich an das neue und die analysierte Erscheinung der Zeichnung konzentriert, und auf die Handels betrachtung so wie die Verkäuflichkeit, Qualität, Kosten und Zeit vergessen kann.

1. INTRODUCTION

Developed nations trade in increasingly competitive world markets where the pace of technological advance demands new products at an ever increasing rate. To help industry meet this challenge it is important that engineers are taught to identify, early in their careers, the correct balance between the many interrelated factors that lead to the development of successful products. Academic subjects are only part of the real world of engineering. For students to obtain a more complete understanding of the whole subject it is necessary for industrialists to be involved in the teaching process. The academic work must not be separated from its industrial implications and practice, as this leads to wrong attitudes that are subsequently difficult to change. The industrial aspects of engineering must be integrated into degree programmes in a way that develops an understanding of the industrial relevance of the material covered. Sandwich courses and university/industry staff exchanges go a long way towards achieving this understanding but they do not really integrate the academic and industrial aspects of the subjects covered. Also both schemes make heavy demands on resources and are rather cumbersome and inconvenient to administer, and neither has the flexibility or impact of a more continuous industrial involvement over a broad spectrum of subjects. Ideally professional people from industry must be brought into the classroom so that they can participate in the teaching of engineering, with academic and industrial aspects introduced and developed continuously throughout the whole degree programme. Lecture courses and project work designed in this manner are effective in developing a fundamental understanding and professional attitude to product design and development.

2. INDUSTRIAL COLLABORATION

This is the type of teaching programme that we are developing for the engineering degree courses at Reading University. At present it involves the active participation of twenty suitably briefed senior
industrialists attending the University for one or two lecture/seminar sessions per year ranging in duration from two to four hours. Where appropriate these sessions are followed by half-day visits to industry where the students meet and talk to committed professional engineers. The object of these visits is to introduce the students to the many commercial as well as technical constraints that effect the development of advanced projects. In addition we have four visiting industrialists giving lecture courses ranging in length from five to twenty hours per year. The courses given by the industrialists relate to the following topics: law, economics, management, business finance, marketing, patents, types of commercial contracts, design, project management, product development, device technology and industrial relations. We are continually striving to increase the effectiveness, extent and variety of our industrial involvement to achieve truly integrated degree programmes.

3. TEACHING ENGINEERING DESIGN

The most recent development in this field concerns the teaching of engineering design. To ensure a successful approach to the design of engineering products, design must be taught in the context of real life engineering and must be seen to be the vital ingredient, the common factor, that brings all the engineering disciplines together in the correct balance which reveals the underlying economic priorities. It is all too easy in developing design courses to concentrate on the innovative stages and analytical aspects of detail design, omitting the more commercial considerations such as marketability and compromises between quality, cost and time. Teaching design in isolation encourages the wrong attitudes and an approach to product design, the end results of which are products that do not compete well in world markets.

This paper describes an attempt to integrate the academic and industrial aspects of the engineering design course which forms part of the Mechanical Engineering and Engineering Science 3 year degree programmes at the University. It involves a collaborative venture between the Engineering Department and the Black and Decker Company in which a product marketed world-wide, is used in a design study project intended to put across more of the essence of design and to stimulate in the minds of engineering undergraduates the vital ingredients of successful product design.

4. BACKGROUND

The engineering design course is taught by University staff and backed up by material covered by visiting industrialists mentioned previously. It comprises lecture courses and a variety of design exercises and project work. As part of this course students had formerly carried out two separate design, build and test projects, one in
the second year and one in the third year. It was decided to replace
the first of these by a detailed study of the design and production
of a manufactured product which had a proven record of success and
with the active participation of the manufacturer. The standard de­
sign, build and test project is a common approach to the hands-on
teaching of design. Whilst we feel that this approach is an essen­
tial component in the latter stages of our courses, we believe it
has too many disadvantages early in an undergraduate's education. The
potential benefits to be gained are limited by the lack of experi­
ence and knowledge of many students. It can easily result in stu­
dents working in semi-isolation on specialised topics in which they
have little interest, and with a level of supervision that can vary
dramatically depending on the supervisor and the importance of the
project in relation to the supervisor's personal interest and re­
search. The technical content of such projects, early in an under­
graduate course, is restricted and the work often lacks commercial
relevance. They also give a false impression of design and the de­
signer's role in developing successful products.

5. OBJECTIVES

What we wanted was a more effective and relevant design project
with industrial involvement. The educational objectives for the de­
sign study project were:
(a) To create a work environment from which students will gain an
insight into the vital role of the design engineer.
(b) To demonstrate the relevance of lecture course material to the
problems of designing real products.
(c) To bring students into contact with industry, to see and app­
reciate the problems of manufacture and production and, perhaps
more important, to meet committed professional design engineers.
(d) To emphasise the relevance to design of some of the more comm­
cial aspects - marketing policy, cost, quality and time.
(e) To bring students into contact with a wider range of academic
teaching staff during the course of the project.
(f) To make some practical measurements, assessment or investigation
relating to a product that has been studied in depth.
(g) To assimilate and digest technical and commercial information
which is then related in the form of a critical, readable, report.
(h) To have the opportunity to indulge in an element of specialis­
ation into areas which arouse particular interest.

Students work in groups of 5 but the key factor is that all stu­
dents study the same product. In phase I the whole class meets each
week for a structured seminar dealing with some specific topic, one
of these sessions being a factory visit, while in phase II groups
work separately on some practical investigation relating to the
product. Having a single product we are able to concentrate our eff­
orts: more preparation, more staff involvement, a real commitment to
the single product but with significantly less total effort than
with a range of products to choose from. We decided to avoid the conventional case study approach which requires the generation of quantities of paper work. Instead we felt that an essential part of the project should be learning to collect and handle the greater part of the necessary information. Furthermore, once paper work for a case study has been prepared there is a natural reluctance to change - with our scheme we change to a new product each year. Another advantage of this project is that at an early stage of the degree course, one can successfully get across the important industrial role of the designer and his need for a working knowledge of a wide range of subjects. This has a motivating effect because the student then develops a feeling for the relevance of engineering subjects to practical problems.

6. CHOICE OF PRODUCT

From our decision to concentrate on a single product the choice is most important. Our requirements for the ideal product are summarised in the following "specification".
(a) It must be such as to provide a teaching "vehicle" for a wide range of disciplines.
(b) The product must be an entity - not a component of some other assembly.
(c) The manufacture should involve as wide a range of materials and production methods as possible.
(d) The manufacturing company must be willing and able to co-operate fully in the enterprise.
(e) The product must be designed and manufactured locally to facilitate factory visits and visits of company staff to the University.
(f) The product must be in volume production for a competitive market.

It will be apparent that the choice of company is very important and we have been fortunate in being able to enlist the help of Black and Decker who not only design and manufacture a range of products ideally suited to our needs, but have also approached the enterprise with a degree of enthusiasm which has been of inestimable value.

The product chosen for study in 1980/81 for the first Design Study Project was a Black and Decker angle grinder (model GD 3116). In 1981/82 we selected the chain saw (model DN 401).

7. THE DETAILS

The programme, as regards choice of product, seminar topics, special study areas, etc. is planned by a group of University staff but the day-to-day running of the project is controlled by a "project co-ordinator".

The time allocated to the design study project consists of 25 three-hour periods comprising one afternoon per week in two con-
8. PHASE I

Phase I covers 13-3 hour periods leaving 7 periods for Phase II. Each period in Phase I is divided into two equal parts, the first consisting of a lecture given by a specialist in the subject area and the second involving group discussions, finishing off with a general discussion.

In the first period the students are given an introductory talk about the product, the objectives of the project, the way it is to be organised and the method of assessment. They are then divided into mixed ability groups and each student issued with a general assembly drawing, a parts list and a detailed specification. Groups are then given a product and, following a general discussion about its design and use, students try it out and finally dismantle, inspect and reassemble it.

Following this period students should be thinking along the right lines and asking "Why is this component metal and that one plastic?" "Why is the housing that shape", "why are there two bearings here?" etc.

In the second period the students meet the designer who, besides discussing the design of the product in detail, gives the firm's background, marketing policy, approach to cost and value etc. This is the most important session because only the designer himself can talk in detail about the constraints under which he developed the product, explaining the logical sequence of the development process and giving the reasons for the particular decisions he took when there were, apparently, several choices open to him. This removes much of the mystery surrounding the product and gives the students confidence, motivating them for the task ahead, because they see what was at first sight a complex piece of machinery did in fact have quite humble beginnings and evolved following a logical step-by-step approach in the design process. During the remainder of Phase I the following topics are covered in detail by specialist lectures, the product serving as a common example to illustrate the way in which one makes design decisions: Motor selection and characteristics, Bearings and gears, Sound and vibration, Air flow and cooling, Materials, Production Methods, Aesthetics and Ergonomics, Industrial Design, Report Writing.

The choice of topics vary with the product being studied. By way of example the session on sound and vibration covers the following: Health and Safety aspects of industrial noise, introduction to the problems covering legal and medical aspects as well as the physics of noise generation, conductance and transmission, techniques that can reduce noise problems, specific problems with the product, measured noise levels, sources, transmission, noise spectrum, discussion
of measures already employed, and other possible measures to reduce level.

In the summer vacation students are required to prepare an interim report for submission and assessment at the start of the autumn term. The object of this report is to ensure that they consolidate the information obtained from lectures with other relevant information, so that they have a good understanding of the product and are prepared for Phase II of the exercise. During the first 3 weeks of the autumn term the remaining topics of Phase I are covered. This includes a valuable session with a Black and Decker industrial designer who reviews his role as part of the design team and gives a talk of industrial design, illustrating the implementation of the principles involved by reference to the product.

In the final session of Phase I the project co-ordinator chairs a general discussion, the object of which is to review the work to date and reassess the design following the summer vacation contemplation. In this period the special topics for intensive study are discussed in detail and students regroup to accommodate preferences.

9. PHASE II

In this phase the groups work separately under the supervision of an appropriate member of staff to make a practical study of some specific aspect of the product. The investigations include: (a) Cooling and airflow; measurement of the airflow and temperature under different operating conditions, measurement of the cooling fan performance and investigation of the potential for improvements from minor design modifications. (b) Noise and vibration; measurement of noise levels and spectra, to establish the relative contributions of different sources of noise investigation of means of reducing noise transmitted. (c) "Market"; study of the competition - price, market penetration, user reaction, etc. Look specifically at the ergonomic aspects of the design, make and evaluate alternative handles. (d) Materials; study the materials employed - measure hardness profiles, creep and impact properties of plastic mouldings, fastener strengths.

Exchange of information between groups is encouraged and reference can be made back to the manufacturers for details of test conditions, material specifications, etc.

Final reports are prepared during the Christmas vacation and are then submitted for marking one week after the start of the Lent term. Oral examination take place during the following three weeks.

10. ASSESSMENT

Assessment of the project is based on the interim report, final report and oral examination.

In the reports, we are looking for a direct and active style giving a clear critical presentation of material assimilated over
the period of the project and showing and underlying appreciation of the commercial and technical factors which have influenced the design. With the whole class studying the design of the same product, the assessment of individuals is much fairer than when they all do something different - one is comparing like with like. The oral examination is of major value in differentiating between individuals and assessing their contribution. There are two examiners for each oral, the student's supervisor for Phase II and the project co-ordinator. Both have read the student's reports and are therefore able to put questions about points which need clarification, and really delve into the student's understanding of the work and their contribution.

11. CONCLUSIONS

Having run the exercise for 2 years, we can say with confidence that it has been successful in meeting our overall objectives. On completion of the exercise students demonstrated a mature understanding of the roles and responsibilities of the designer in competitive industry. The exercise also demonstrated the very real benefits derived from interaction between undergraduates and the designers of the product. An enthusiastic, committed designer talking in detail about his work is worth any number of "academic" lectures, also having members of the University staff demonstrate, in depth, the relevance of their own subject to a common problem, worked very well. The various subjects were brought together in a way that showed clearly their common purpose and overlap in developing competitive products.

REFERENCES


PRODUCT DEVELOPMENT FOR THE OFFSHORE INDUSTRY: A CASE STUDY

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ABSTRACT

University based research into embedded anchors suggested that a system could be developed to provide a multi-purpose off-the-shelf anchor. Following a patent application and commercial appraisal, a substantial grant was obtained from the Wolfson Foundation to develop the invention. A company, OMC Anchor Technology Limited, was formed to undertake the development. Events are traced which relate to background work prior to the formation of the company, in addition to subsequent areas of activity. These include technical investigations and developments, product protection, licensing and marketing. Some features relevant to the innovative process are discussed, with reference made to the influence of engineering education.

RESUME

A la suite de recherches menées dans une université au sujet d'ancres enfouies, la suggestion a été émise qu'un système soit élaboré pour produire en grande série une ancre à usage multiplex. Suite à une demande de patente et à une critique commerciale la Foundation Wolfson a octroyé une bourse substantielle pour développer l'invention. Une compagnie, OMC Anchor Technology Limited, a été créée pour en mener à bien le développement. Le projet comprend des éléments qui remontent à avant la création de la compagnie, en plus de plus récents domaines d'activité, notamment des enquêtes et des développements techniques, une étude sur la protection du produit, ainsi que le brevetage et le marketing. Des discussions concernant certains points du procédé d'innovation sont en cours, en corrélation avec l'influence de l'enseignement de la technologie avancée.

ZUSAMMENFASSUNG

Die Hochschulforschung im Bereich fester Verankerung ließ darauf schließen, daß ein System entwickelt werden könnte, um einen vielseitig verwendbaren (direkt lieferbaren) Anker zu ermöglichen. Als Folge der Patentanmeldung und kritischer Bewertung von sieben der
1. INTRODUCTION

The evolution and development of conventional drag anchors, which form the bulk of anchors presently used, has taken place over several thousand years and the factor dominating development has been anchor configuration. This factor governs response to loading, cost and ease of installation resulting from a placement procedure which has not differed greatly for most anchor types. A range of drag anchors is available which has a behaviour largely sensitive to soil type, a fairly low efficiency and reliability, and unidirectional loading capacity characteristics.

With the recent rapid expansion of offshore exploration and resource development, the range and sophistication of anchor systems required for a variety of tethered facilities has produced a considerable research and development effort (Harvey et al., 1978, McCormick, 1979). Clearly, to develop an anchor with a high efficiency and reliability capable of developing multi-directional restraint in a range of soils requires a substantial scientific and engineering application. An additional and important requirement for commercial success is economic acceptability which, in this case, is not merely influenced by anchor configuration but by the whole design philosophy embracing choice of hardware and mode of installation.

Early experimental work indicated that a configuration made up of three components, i.e. a top thrust member connected by means of a shaft to a bottom fluke system, see Fig.1, produced a highly efficient anchor with excellent response characteristics to general loading packages. Calculation suggested that these characteristics would be retained for prototype systems and, in addition, confirmed that placement could be achieved by impulse driving. Finally, a comprehensive cost comparison indicated substantial savings which compared to competing anchor systems.

A patent application was made and first stage presentations given to a number of organisations representing user and supplier interests in the offshore exploration field. With industrial backing an application was made to the Wolfson Foundation for a grant of £238,000 over three years to carry out the development. This was obtained in the latter part of 1976 and the main research and

Flukes clamped together

Installation frame
and hammer

During driving

Flukes open

Seabed

Thrust member

Shaft

Installation complete

Fig. 1. OMC Anchor.

2. SETTING UP THE COMPANY

OMC Anchor Technology Limited, a subsidiary of OMC Industrial Research Limited, which is wholly owned by Queen Mary College, University of London, was set up to develop the anchor invention and also to undertake, or license, the manufacture, marketing and installation. The reasons for operating in this way ranged from taxation and liability considerations to the eventual use of the company as a basis for a possible joint venture activity, discussions to this end being already underway, and as a trading organisation when the anchor development was complete.

Senior staff from the holding company assumed the senior management positions of the new company and the inventors of the anchor took overall technical responsibility. As they also had academic commitments as university teachers, a full-time project manager and two full-time technicians were employed. In addition, a considerable technical input was made by a number of research students on higher degree programmes.

Substantial difficulties were found in attracting high calibre staff for a short term contract with no guarantee of continued
employment at the end of the development. A delay of almost six months occurred before the full team was assembled.

3. PRODUCT PROTECTION

During the early stages of the university research programme, several years before the Company was formed, there was an awareness of other groups working in related areas and, in retrospect, it would have been sensible at all stages of the development to have worked in complete isolation. However, the disclosure of information by the inventors, in earlier publications, which is the accepted academic currency, made patenting a more difficult and expensive operation as some state of the art was then in the public domain. The balance between publishing and product protection presents a conflict of interests which can only be resolved by a close knowledge of patent procedure. Such procedures should be drawn attention to during the initial formation of an engineer.

Impetus was given also to the work of rival groups by the release of information in private discussions. In the last few years, however, it is believed that the more open dissemination of information from universities, that has hitherto taken place, has been somewhat stemmed. As this particular development proceeded, information was disclosed only under confidentiality agreements.

Discussions with interested industrial partners highlighted the importance of a strong patent position and firms would not commit themselves until this was established. The necessity of extending protection worldwide can be a considerable expense and, perhaps, beyond the resources of a small company. Fortunately, an agreement was negotiated with a large industrial partner who undertook, as part of the agreement, to extend the protection to ten major industrial countries considered capable of manufacturing and installing the anchor.

4. TECHNICAL INVESTIGATIONS AND DEVELOPMENTS

The aim of the technical investigations, based on the Wolfson monies, was to develop a small prototype anchor suitable for a per anchorages, if required, and capable of being installed, to a specified attitude, from a remote controlling vessel. Although the anchor itself was novel and required development, it was considered important that all supporting technology was already available.

The early stages of the programme leaned heavily on medium scale laboratory testing. Scale effects were believed to be small, at least under sustained loading, and hardware alterations, particularly to the fluke mechanisms, could be made quickly and inexpensively.

It was established that self-opening flukes driven in the closed mode to a 'keying activation' level, and subsequently keyed below this level, provided an installation resilient to repeated loading.
The most suitable configuration for the self-opening mode was predicted by analysis and, after proving at laboratory level, prototype tests were undertaken. Installation and load testing was carried out on land at a number of different sites which behaviour could be carefully monitored, and successive laboratory developments, e.g. explosive bolt activation of the flukes, were subsequently incorporated at prototype level.

At the conclusion of the prototype tests on land, the acceptability of system response to both sustained and sustained-repeated loading had been demonstrated, together with the effectiveness of the installation technique. Installation was achieved by driving the anchor into place using an environmentally sealed hydraulically actuated hammer, and this component formed the basis of a versatile installation package which can be lowered to the sea bed. In order to operate in this mode, levelling indicators ensured the correct attitude in the horizontal plane and threshold switches on the frame, hammer carriage and fluke locking mechanism monitored the progress of the installation, together with the unlocking and opening of the fluke system. Many of the smaller components were tested in the laboratory in pressurised water vessels, thus simulating 'at depth' conditions, before the underwater trials were conducted.

The sea trials proved the performance of the complete underwater installation package, including satisfactory retrieval and reloading for re-use. The underwater driving and installation attitude is shown diagrammatically in Fig. 1.

5. LICENSING AND MARKETING

In order to move quickly into the larger capacity anchor market, it was essential to fabricate and test a larger version of the anchor, as the major users operate on a 'show me' basis. As a first stage assessment of the market suggested that there would be a significant demand for such a product, approaches were made to a number of British companies to locate a licencee prepared to contribute to the development. British companies showed a reluctance to participate, but a non-exclusive licence agreement was negotiated with a major company from the United States. Existing technology was purchased by the licencee who undertook to carry out larger scale development work in addition to the marketing operation. This latter activity was particularly important as it was felt that OMC Anchor Technology Limited were not in a strong position to deal with large scale marketing in the offshore business.

Unfortunately, towards the end of 1979 the licencee, in view of financial difficulties and other factors, felt unable to continue and cancelled the agreement. At that stage it had been concluded that a market existed for the smaller anchor but was difficult to quantify. Additionally, and consistent with the earlier, first stage market assessment, major companies had substantial demands for a large anchor, but no marketing potential would exist until large
scale testing had been conducted on a fairly extensive basis. It was found that, for a number of applications, more expensive product substitutes were highly competitive, notwithstanding the cost advantages of the OMC product. Although, in the early stages, this was believed to be a vital component of commercial viability, the anchors, in some cases, form only a small part of the total cost of a moored facility. Thus, competitive prices are of less importance and technical considerations tended to dominate marketing discussions in which most users displayed a conservatism often characteristic, with justification, of offshore operators.

To date, a considerable effort has been expended on marketing the smaller developed anchor and a number of design schemes submitted for offshore projects. Several proposals are awaiting decisions and negotiations tend to be protracted. The excessive outlay of time and money puts severe financial strain on a small company and emphasizes the difficulty involved in breaking into a high technology market with comparatively few product outlets.

In other and related areas, however, a number of contracts have been obtained and a gradual increase in business activity has taken place. It is anticipated that this will continue to grow.

6. THE INNOVATIVE PROCESS

The anchor work developed from investigations into cable roof anchorages when it became evident, over a period of time, that offshore anchorage was an area worthy of investigation. This change in direction was made only after the formulation of a clear idea of the problem and that a solution could be produced in a reasonable time. At that stage the commercial benefits of a successful development were difficult to quantify, although some authors (Thring et al, 1977) have suggested formulae to give guidance. The anchor project was open-ended and presented itself, not as a single problem, but as a set of problems and, initially, it was considered important to have some form of workable solution to all the anticipated difficulties. Thus, the solution chain was continuous. Rather than produce elegant solutions to discrete parts of a broken chain, attention was focussed on all problems and, systematically, improvement made by a process of successive approximations, sometimes by brainstorming.

Often solutions were obtained with the assistance of simple models to produce practically achievable configurations and placement techniques. In order to proceed along these lines, an engineer must have experience based on related fields of study and a knowledge of what is achievable in terms of materials and operational considerations. Whereas mathematicians may be more creative in the earlier years of their career, an engineer is dependent on a large amount of empirical data, compiled over years of experience, in order to develop creative solutions. These are developed from a blend of knowledge, skills and attitudes together with a sense of commercial reality.
It is believed that design and project work carried out in the earlier years of engineering formation are valuable stepping stones in fostering a creative problem-solving attitude. Engineering education depends on the synthesis of a multiplicity of components and this synthesis normally takes a number of years to achieve. Techniques to accelerate this process during initial formation are essential and should contain activities that reflect those of the innovator. Critical appraisal, although important, should be considered subordinate to creativity as the former is encompassed by the latter. It is to be regretted that the advent of the applied scientist in British universities has caused greater attention to be focussed on critical appraisal rather than innovation, the prime aspect of engineering and the engine of growth in an economy.

7. CONCLUSIONS

A university based company is well suited to handle research and development programmes but can be at a disadvantage when marketing a product resulting from such a programme. The initial education and training of British engineers, e.g. a university degree, often largely engineering science, followed by several years practical experience to become chartered, is appropriate for technical competence in research and development work but, unfortunately, perhaps engenders a preoccupation with technical career patterns.

For the role of the engineer to be more than just subordinated to the technical domain, it is important to have a firm grasp of other areas. Although education and training for an entrepreneurial role is needed in an engineers career, and should be obtained largely by continuing education, an appreciation of these needs should not be overlooked during initial formation. This must not be at the expense of engineering science but by inclusion in enhanced degrees extended to four years of study. It has been suggested that British engineers are not as well prepared to operate effectively in broader areas within the engineering dimension than counterparts elsewhere (Finniston, 1980), and may be one of the reasons for a lesser involvement in new technology based businesses and, perhaps, for the dramatic British decline in innovative activity when compared to other nations (Tomkins, 1980).

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COOPERATION WITH THE INDUSTRY - AN ESSENTIAL CONDITION FOR INNOVATION

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ABSTRACT

Innovation and entrepreneurial activities ask for selection procedures. The selection procedures include market information from the industry and therefore cooperation with them is essential. The combined action of industry, student and university includes exchange of information; for the students it means to learn how to innovate. The last part of a technical education at departments with an applied technical character should be devoted to stimulation of an innovative attitude.

RESUME

Dans activités innovatives et entrepreneuriales procédures de sélection jouent un rôle important. Pour procédures de sélection information du marché de l'industrie est indispensable et pour cette raison coopération avec elle est essentielle. Dans l'ensemble industrie, université et étudiant mutuel transmission d'information a lieu, ce que signifie pour l'étudiant apprendre d'innover. La dernière part de l'étude dans départements avec un caractère technique-appliqué doit stimuler cette attitude innovative.

ZUSAMMENFASSUNG


Three is the charm of many things. Live gives us many examples to prove this. Three is a number however which does not come very easily in the mind of those participating in academical technical educa­
tion. If a technical university would limit itself to the teaching of fundamental subjects, there would be no objection to distinguish only two parties; scientific staff and students. If a technical university claims to contribute also to innovation it is unrealistic to ignore the existence of a third party; the industry. When the present day students were still at the secondary school they were supposed to dream about their future as a qualified engineer. That is quite normal because at that age phantasy plays an important role. It is questionable if those youngster were paying much attention to the university. It is very likely that they regarded the university only as a barrier to be taken. After one year of enrolment at the university they discover that they have underestimated the height of that barrier. The university will have to concentrate the teaching effort in the first two years mostly on fundamental aspects (first the tools and then the application). It will be clear that under these circumstances there is little time available for the exploitation of the students' creative thinking ability and also for the stimulation of their innovative approach to problems. Each experiment meant to encourage the use of phantasy at this stage is time consuming for the teaching staff. It is easy to understand that much attention has to be paid to restore creative thinking and to reestablish a "prepared" mind for innovative solutions of the students when they enter the last semester (1 - 1½ year) of their study. If this does not happen little is left of the expectations the students nourished in their pre-university period. The education of students to undertake innovative and entrepreneurial activities is hard to describe. It comprises a sequence of aspects:

a. phantasy to generate ideas

b. the conviction that those ideas are worth realizing

c. the courage to distinguish promising from non promising ideas.
   The word courage is used here because one needs rudeness to survive this operation - normally one out of ten is a feasible idea. A multi disciplinary approach is necessary to sort out the promising ideas as it involves economical calculation and market information.

d. Modelling in the sense of what is the main feature of the new invention. This kind of modelling is the interface between idea and use of fundamental tools as mathematics and physics. This introduces the next aspect in the sequence of innovation.

e. Ingenuity in the use of the fundamental tools as mentioned before and programming for the computer etc.

f. Skilfull experiments; minimum adequate ones to sieve out once more promising from non-promising ideas. This scanning eliminates another 90% of the ideas left over after stage "c".

It may well be that innovator and entrepreneur have to go many times through the innovation sequence.

What are the advantages to go through the procedure at a technical university with students.

In the first place: the environment is well known to the student.
He should not be afraid of asking stupid questions. Secondly: the student is forced to communicate with a variety of disciplines in the selection steps of the innovation sequence. Therefore he has to learn to formulate his problems very clearly (verbal and in writing).

Thirdly: if a student is exposed to this sometimes unpleasant situation in the industry it coincides with the problem of getting acquainted with the industrial world.

Apart from the students there is the training of the staff members of the university with respect to the most appropriate way to restore the innovative thinking of the students and adapting to this end the research and teaching program.

In the innovation sequence as described before the crucial steps are the selection procedures. The university may have the disposal of economical orientated departments; they are however of little value if the field- and marketing information is not available. Contact with the industry is therefore very essential; it should be broad and intensive. The student must feel that he is involved in real problems and not in problems generated by his professor. Accepting the industry as a third party beside students and staff members the question may be raised to what extent the contacts are beneficial to all parties. What are the dangers to regard the industry as the party in the education for entrepreneurial activities. In order to answer this question it is very helpful to distinguish three types of industrial companies: small companies (50 employees); medium large companies (50 - 500 employees) and large companies (more than 500 employees).

The cooperation with the industry is also affected by the kind of problems, that is to say: long range, medium range and short range problems. Each combination of different kind of problem and industry has its own features.

1. Large companies with long range innovative problems
This is an easy combination to deal with. The research and development group (R/D) of a large company has gone through the innovation sequence many times; idea generation, the persistency to introduce promising ideas, the idea selection, etc. For this reason such a group is very instructive for both student and staff members of the university. The R/D group of an industry knows exactly what can be expected from an university; strong in the introduction of fundamental tools but mostly weak in improvisation. The R/D group of this kind of industries is able to describe the long range problems very clearly. Generally speaking there are sufficient manhours available on the industrial side to discuss the progress in the research program and to warn for possible pitfalls. They do not insist on tight time schedules for the research program as long as the university is diligent in trying to solve the problem. As large companies have enormous amounts of know-how themselves it is not risky to carry out confidential work with the university, moreover there should be secrecy agreements. The conditions for cooperation between university and industry may be favourable in this case. Not yet discussed is the question who profits most by such a joint research effort. As it
is a long range problem it is elaborate enough for doctoral work. It has a teaching effect on the students and the university because it is supposed that the problem under study fits in the research program of the university. Against this twofold advantage for the university stands the fourfold advantage for the industry. It is a cheap way for them to receive basic know-how for their innovation sequence; the research work is carried out by an outsider on a temporary basis; they support the university to produce useful qualified engineers; the cooperation with the university has an advertising element for their recruitment. As in total the main advantage is on the industrial side they are inclined to support the research program financially. They are sometimes also inclined to pay a small reward if a patent would arise from the cooperation. As illustration following examples can be given for long range problems with large companies. On the one side Laboratory for Process Equipment of the Delft University of Technology and on the industrial side:
- Sundyne U.S.A. (high speed centrifugal pump)
- Several process industries (mechanical seals)
- A.C.V.; Sulzer (improvement packing for vacuum rectification)
- AKZO; I.C.I. (improvement of their crystallizer for sodium chloride; increased purity; lower energy demand).
All above mentioned improvements have lead to industrial application.

2. Large companies with medium long range innovative problems
Most of the arguments mentioned under item 1 are also valid for the combination of large companies and medium range problems. As the duration of these medium range projects is rather short it is not possible that the problem to be studied can serve as basis for a doctoral work. For this reason the project has to be handled by staff members of the university; if experimental work has to be undertaken they will be in charge of these activities. In case it is for financial reasons impossible to do any research there is another way for staff members and students to participate in innovative projects like this. It can be incorporated in the teaching program as an elaborate exercise. Looking at the innovation sequence it can be understood that students in the final two semesters of their study can play a role in the selection-, modelling- and fundamental stages. The students will discover what it means to be innovative. The above mentioned stages ask for teamwork because they include technical and economical aspects. In the area of equipment for the process industry a number of examples can be mentioned. They all concern alternative process equipment in the process industry in order to limit energy demand, diminish environmental load and decrease raw material consumption; for instance improvement of "cat cracking" of oil, offshore treatment of oil and gas (top side facilities), xylenes production, fatty acids, etc. In these medium range projects 20 students are innovated during 40 days.

3. Large companies with short range innovative problems
In view of the duration of these problems it is practically impossible to do any experimental research in depth. These projects can be
incorporated in the last period of the teaching program (duration 20 days). Innovative aspects which can be studied are idea generation and preselection. Most of the students regard this as the most stimulating part of their study which may be sufficient to restore innovative thinking.

4. Medium large companies with long range innovative problems
Such companies have some experience with innovative procedures. The manpower (R/D) resources are relatively small. They tend to make short cuts in the innovative procedure. It is inherent to their existence "flexibility". As they have not enough patient money they may tend to take risks. Such long range problems should in principle be suitable for doctoral work but there is the danger that the thesis will describe very briefly successful and unsuccessful attempts.

Another problem with the combination medium large companies and long range innovative problems is that the research effort of the university may become equivalent or sometimes even larger than the effort of the company. In case of doctoral thesis the industry may try to interfere in the research program on an acceptable scale. It is incorrect to think that cooperation with a medium large company is not instructive for students; it stimulates the flexibility in thinking and the entrepreneurial attitude and they get acquainted with the typical problems of those companies. It is due to the nature of the university that cooperation in this particular case is sometimes difficult.

A professional research organisation is a more attractive party for this type of companies; it is more efficient than the university (no teaching load), there is no danger of conflict of interest in the research program, etc.

5. Medium large companies with medium long range innovative problems
As mentioned before the duration of the problem is too short for a doctoral thesis. The project has to be handled by the members of the staff of the university. It will be very difficult to get these projects financed by the Dutch government. It should be noted that the Dutch government is promoting long range research. If the medium large company would take care of the money the out of balance situation would remain. As discussed in one of the previous sections (4) the know-how of a medium large company is limited. For an effective cooperation in innovation activities all know-how related to the project has to be open for discussion and in practice this may be all the know-how a company possesses. A secrecy agreement could eliminate this aspect to a certain extent but the peculiar situation remains.

Dealing with medium range problems the contact between the parties will be relatively short and there is no time for the parties to get acquainted with one another which makes the secrecy problem more serious. For students, staff members and industry the attractive side of the cooperation is the teaching effect.

6. Medium large companies with short range innovative problems
Not every experimental work at the university fits in short range problems and therefore the contribution to a solution for the problem
has to be incorporated in the teaching program. It is attractive to participate in the first stages of the innovative sequence. Staff members of the university and students can generate ideas and separate the promising from non-promising ones. The final selection must be carried out by the medium large company on basis of its own experience. Any substantial experimental work should be carried out by a professional organisation.

7. Small companies with long range innovative problems
This combination will only arise in very special cases. There is not only the problem of finding financial sources but also the lack of an adequate counterpart who can absorb the gained knowledge. The so-called R/D staff of these companies are that small that only for instance 4 manyear can be made available. Small companies have only a faint idea of what a technical university can do. If the cooperation would lead to the possibility to write a Ph.D. thesis a number of interesting aspects could never be published as the private knowledge of the company would be involved. In this case it would be very logic that the Ph.D. man goes over to the small company. It is questionable, however, if such a company can afford the payment of his salary. It takes time to introduce a new product on the market, even with an entrepreneurial attitude. It could be that the expert takes another job and the small company will have to rely on the know-how of an "outsider". An outsider is unable to cope with the flexibility of small companies. Employees for development, marketing and production should be located as close to one another as possible. Despite these problems long range and intensive contact between university and small companies is an eye opener for all parties, for instance during exchange of basic know-how and field information (v.v.)

8. Small companies with medium long range problems
Most of the peculiarities mentioned in the previous section are also present here. In many cases there is one basic difference. In a medium long range problem the small industrial company is mostly well aware of the value of its innovation; what fails is sufficient experience in handling the elements of the innovation sequence modelling, use of fundamental tools, small scale and simple experiments. The R/D employee of the industry will obtain the missing elements of the innovation sequence. The joint effort does not solve only the technical problem but it also stimulates the exchange of experience. Direct applicable "fundamental" knowledge is transferred to the industrial company and field information to the university, to the staff members and students.

9. Small companies with short range innovative problems
As already indicated in the two previous sections with small company is not meant companies with no or scarcely any development facilities. Those companies have to wait for the lucky dipp in some or other market area in order to survive. When small companies contact the university for a short range problem it is not necessary for them to give insight in all their know-how. In many cases the university is in a
position to assist at short notice as no money is involved for experimental work. Immediate response of the university is essential in view of the required flexibility of small companies. The contact with small companies with short range projects contains a wide variety of missing links in the innovation sequence and therefore it is very instructive for both students and staff members. As mentioned before it is also instructive for the small industrial company as it receives not only a possible solution for the problem but also background information. It will upgrade its technical and commercial activities. The assistance to the small company should be such that there is no need for further support for quite a long time which is the major difference between the assistance of a technical university and a professional research institute.

From the foregoing description of the aspects associated with contacts between technical universities and industries follows that the description is primarily meant for laboratories and departments in charge of applied technical sciences. It is their task to keep the gap closed between fundamental tools and market orientated innovations. It may be concluded from the different situations arising from cooperation between industry and university with respect to the size of a company and the kind of problem that the "best fit" is obtained in case of short range problems with small companies and long range problems with large companies. Apart from the matching aspect there is the question to what extent an university is able to play a role in the innovation sequence. It may differ from laboratory to laboratory but in general it is hard to believe that an university is able to go through the innovation sequence from grass root to a fully market accepted innovation. Anyhow during her 33 years existence it has never happened at the Laboratory for Process Equipment of the University. It has supplied background information (for long range problems) in order to facilitate the birth of innovations; it has handed over the spin-off of their research (in particular to small companies) and it has tried to restore creative thinking of students and their alertness for new ventures and it has strengthened their sense for information. Following information may serve to quantify these statements. The laboratory has participated in short range projects during the last three years. In the same period it has received f 1.500.000,-- from industry with the object to maintain the research facilities (mostly long range problems for large companies) which means an average of f 500.000,-- per annum. If to this amount the contribution of the university is added the total cost for innovative education can be calculated. The contribution of the university consists of three parts: 1. investment in a research building f 4.470.000,-- or per annum f 250.000,-- (depreciation and maintenance), 2. personnel costs for research f 639.000,-- per annum. 3. Instruments, equipment f 400.000,-- per annum. Total amount including the contribution of the industry about f 1.800.000,-- per annum. Average yearly "production" of qualified engineers is 14. Investment for innovation per qualified engineer is f 130.000,--. Against this investment stands the earning capacity of a qualified engineer (from
an university) during his active period of 35 years in for instance the process industry. The total sales of the process industry during the last 3 years based on 1982 price level amounts $f \times 10^9$ or per annum $f 130 \times 10^8$. Number of university trained employees in the process industry is 11,000 so the sales/manyear $f 12,000,000$, or during the 35 years active period in total $f 420 \times 10^6$. Comparing this amount with investment in education aimed to stimulate innovative and entrepreneurial thinking it is clear that the money is well spent, even with a modest profit on total sales from process industry.

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A MULTICOUNTRY STUDY OF THE ROLE OF ENGINEERS IN INNOVATION

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ABSTRACT

There is growing interest in all SEFI countries in the role of the engineer in innovation. Many factors that affect this, however, vary between countries rather than within them. It is therefore proposed to carry out a multicountry study of this topic, which involves the same questionnaire being completed by graduates of leading engineering schools in a number of European countries.

RESUME

Dans les pays SEFI on s'intéresse de plus en plus au rôle de l'ingénieur vis-à-vis de l'innovation. Comme les facteurs qui influencent ce développement varient entre pays, nous proposons d'entreprendre une étude multi-pays de ce sujet qui sera basée sur d'ingénieurs dans plusieurs pays européens.

ZUSAMMENFASSUNG


1. INTRODUCTION

This paper describes a proposed multicountry study of the role of engineers in Innovation. The initial idea for the study and the preliminary design work were undertaken by the European Communities Research Centre at the Bradford University Management Centre which will also be reasonable for overall coordination of the study and the bulk of the data analysis. Datagathering will mainly be undertaken by participating institutions and is expected to begin in Autumn 1982.
2. BACKGROUND TO THE STUDY

Concern about the performance of engineers in innovation has been voiced in many different countries in recent years and has been the subject of much discussion within S.E.F.I. What is not certain is how differences in the performance of engineers in innovation are related to such variables as education, status and work situation.

In attempting to study these questions however there is an obvious difficulty that in every European country engineering education is subject to substantial central coordination and thus differs more across countries than within them. Similarly in any given country many of the variables connected with the social status of engineers or their work situation exhibit only restricted variation, at least compared with the variety of practice in Western Europe as a whole. Such situations, of course, provide the classic argument for a multicountry study in which the desired variation in variables of interest is achieved through existing country differences. We have therefore designed a research project to examine the contribution to innovation in industry of engineers in a variety of European countries.

To assess contributions to innovation during their careers requires a study of sets of engineers who graduated at various ages. To obtain significant data requires much detail from samples of engineers of each age in each country. The research is therefore a major undertaking and requires cooperation with colleagues in various countries.

3. INNOVATION AND THE ENGINEER

The underlying definition of 'innovation' used in the study is essentially that of Schumpeter (1939) viz: any change leading to an alteration of the production function of an organization. In adapting this definition to the work of the engineer we have on the whole interpreted this idea broadly just as Schumpeter himself did. In particular we shall be paying especial attention to the involvement of the engineer in the introduction of new products, in technology licensing and in the formation of new businesses.

An underlying theme in much of the discussion in the S.E.F.I. countries of the effectiveness of engineers in innovation is that matters are deteriorating at least by comparison with Japan. This is of particular interest at the present time because a number of commentators (ACARD, 1979; Mensch, 1979) following Schumpeter's (1939) vision of innovation as the engine of economic growth have looked to an upsurge in innovation during the next decade or so for a revival in the fortunes of the Western economies. More prosaically there is a growing belief that a number of new technologies based on developments in genetics, electronics, etc. have reached the stage where they will spawn a large number of innovations that will rely heavily on the contribution of engineers for successful introduction (c.f. The Economist, 1981).
In short there is a widespread feeling that more attention needs to be paid to improving engineers' ability to innovate successfully and that this will become even more important in the next few years (c.f. Tomkins, 1980). At the same time there is not in our judgement sufficient information available to say with confidence how this can be done. Basic data such as the proportion of time spent by engineers on innovation related activities is not really available for even one country, yet to gain a feel for those factors that affect innovation comparable information is needed for several countries. As far as the dependent variable is concerned our purpose is just that: namely to measure with the same instruments a number of different aspects of the involvement of engineers in innovation in different countries.

4. THE INDEPENDENT VARIABLES

The primary concern of the study is to provide information for policy-makers that will make it possible to forecast what policy initiatives will lead to an improvement in the performance of engineers in innovation in the future. For the reasons already given data concerning these variables have to be collected on the same basis in each of the countries involved in the study. A large number of such variables appear to be potentially important. They can however be split into five broad groups, i.e. those related to:

i) EDUCATION OF ENGINEERING GRADUATES
ii) POSTGRADUATE EDUCATION
iii) THE WORK SITUATION OF THE INDIVIDUAL ENGINEER
iv) THE SOCIAL SITUATION OF ENGINEERS
v) INSTITUTIONAL BARRIERS TO INNOVATION ON THE WORK OF THE INDIVIDUAL ENGINEER

5. DATA COLLECTION METHODS

Data will be collected in three ways:

a) from publicly available sources (directories, university records, examining bodies etc.),
b) by questionnaire, and
c) by depth interviews.

The major method of datagathering will be through a questionnaire which will be administered to three 'graduation year cohorts' (1955, 1965 and 1975) from a number of leading European engineering schools. Pilot studies, questionnaire administration and follow up will be the responsibility of each school. The use of graduation year cohorts means that it is not merely possible to identify changes in the behaviour, experience etc. of graduate engineers as a group over time but also differences in, say, early career experience between 1955 and 1975 graduates.
Far richer information can, of course, be gleaned from semi-structured interviews and it is intended that a small percentage of selected individuals will be interviewed in depth if

a) they have started a new firm
b) they hold or have originated a substantial number of patents
c) they have been involved in establishing licence agreements
d) they have worked abroad for any length of time

As always in multi-country studies the variations in the independent variables across countries will be used to isolate their effects. For this reason it was considered that at least five countries participating in the study, including the UK, was needed for the project to be worthwhile. This has now been achieved and it is expected that at a minimum, engineering schools from Denmark, France, Italy, Sweden, the UK and West Germany will be cooperating in the study.

6. METHODS OF ANALYSIS

All questionnaire responses will, after postcoding where necessary, be put up onto a computer database at Bradford. To this end considerable thought has already been given to precoding responses and this will form a major topic of discussion with participating institutions before the questionnaire is finalised.

Traditional data reduction techniques such as factor analysis will be applied to the quantitative data along with a variety of scaling techniques particularly of the multidimensional type. Given the emphasis on explanatory/predictive models of innovation considerable use will be made of relevant multivariate analysis techniques to test models of what affects innovation by engineers. The structure of these models will be based on existing theory in economics, organisational analysis, etc. and information derived from the interviews.

The aims of the analysis are thus more ambitious than in most preceding surveys of engineers. In particular a considerably greater emphasis will be placed on the use of statistical analyses.

7. PROJECT SCHEDULE

The schedule for the remaining stages of the project is as follows:

By end September 1982:

Finalize preparations for data collection by participating institutions.
October 1982 - September 1983:

Data gathering

January 1983 - September 1984:

Data Analysis/Publication of results.

8. BENEFITS OF THE STUDY

It is believed that the major benefits of the study will be as follows:

i) It will provide a comprehensive picture by country and by branch of engineering of the importance of innovation related activities to the job of the engineer. Amongst other things this should provide important information as to the extent to which more emphasis should be placed on this aspect of the engineer's job during his training.

ii) The cohort design should make it possible to separate trends from the effects of career progression. It should thus provide a basis for forecasting the future role of engineers in innovation.

iii) It should identify ways of improving engineers' ability to innovate successfully. This is of obvious interest to a variety of decisionmakers.

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ABSTRACT

Design is the essence of engineering practice. Students need experience in synthesis to become more effective practicing engineers. Design projects and engineering cases are complementary and supplementary ways of providing this experience. Both are discussed in this paper.

RESUME

Le dessein est le fond de la technique de l'ingénieur. Il faut que les étudiants pratiquent la synthèse afin de pouvoir exercer plus effectivement la profession d'ingénieur. Les projets de dessein et les exemples de problèmes techniques rencontrés dans le métier d'ingénieur constituent des méthodes complémentaires et supplémentaires pour leur donner cette expérience. Ces deux méthodes seront examinées dans la présente étude.

ZUSAMMENFASSUNG


1. INTRODUCTION

The essence of engineering is DESIGN, i.e. solution of a great number of multifaceted and multidimensional problems which relate to human needs and desires. How then, can engineering faculty help students develop into effective designers? They must develop a problem-solving attitude in students at the earliest possible opportunity and reinforce this attitude as much as possible. This is not an easy task!

It is my belief that 'design' cannot be taught, e.g. in the sense
that calculus, basic mechanics, etc., perhaps can be taught, I be-
lieve that 'design' must be experienced, i.e. it must be learned by
doing it, by living it. The most effective way of learning design
is through projects. These should start the first day the engineer-
ing student attends classes and continue throughout the entire cur-
riculum until graduation (at whatever level). Obviously, initial
projects should be relatively simple and increase in difficulty and
societal considerations as the student moves through the curriculum.

Does this mean that basic physical and engineering sciences are
downgraded or ignored? Absolutely not! Basic sciences are fundament-
al and essential. Basic sciences provide necessary mental exercise
and conditioning as well as necessary knowledge upon which engin-
eering practice is built.

Emphasis in these courses, however, can be shifted without loss.
In fact, this shift can be very profitable. Many of these courses
now seem to be taught as sciences for the sake of science. A shift
to put emphasis on application would provide motivation and a prob-
lem solving attitude.

Good design projects force students to recognize several factors
of importance to a professional career, namely: few problems are
entirely in one engineering 'discipline', many other factors influ-
ence the eventual outcome; there may be a number of acceptable solu-
tions to any given problem; communication (graphical, written, oral)
is extremely important; economics are always a major consideration;
political considerations are sometimes important and often over-
riding; and so on.

2. DESIGN PROJECTS

Design projects in the university environment range from simple,
short, 'fun' projects involving a few individuals per team to rather
complex projects (up to a year) involving societal, as well as tech-
ical, aspects with teams of several individuals of various kinds of
expertise. From a different viewpoint, these range from campus-only
to industrially or urban oriented projects having a large societal
dimension. Large scale design projects seek to give students a valid
'commercial world' experience. Many academic institutions have used
projects in the industrial and urban 'worlds', using student teams
having an interdepartmental (and inter-college) mix. While I was at
the University of Detroit, urban oriented projects were tried which
had two additional unique aspects: (1) students at different aca-
demic levels worked together in teams, (2) under student project
managers having essentially complete responsibility and authority
for the project.

A project undertaken with Detroit General Hospital had a student
team of 40 (freshmen, senior and graduate students) from such di-
verse areas as engineering, sociology, psychology, philosophy, and
nursing. Each student made a commitment to participate for two con-
secutive semesters of 16 weeks each. Problems abounded in the Out-
patient Department: in the appointment system, in retrieval of medical records, in allocation of space for some forty specialty clinics, and in provision of many-ancillary services.

The end result of the effort was that the total team made a number of recommendations to hospital management. Many of these were successfully implemented. Similar projects were undertaken with the Detroit Fire Department and the Department of Parks and Recreation. Focus was on specific problems within the agency. In all projects, some recommendations of student teams were accepted and implemented. This is sufficient justification (apart from the educational experience) for such an effort in an academic program.

Selection of student project managers is critical. We believe it necessary to recruit them a year in advance so they can begin to function together, explore project possibilities to make a selection, and organize for their year of management responsibility. Operation of a student-managed project solving real problems for off-campus organizations, especially city agencies, presents an ample number of opportunities for operational disasters of various sizes for both students and client. It is not appropriate activity for the faint hearted!

Despite all the potential problems, there are excellent lessons to be learned. Team members believed there was little increase in their technical knowledge, but they did experience applying what they knew in a real context. This not only showed them that knowledge gained in the classroom has reality, but they also found that combining various pertinent items of knowledge is necessary to achieve solutions to real problems. They learned much about team operation with necessity of group planning, division of effort, and coordination of activity. The fact the City of Detroit used some of their recommendations gave students a surge of confidence in their personal capabilities and in being able to 'sell' their ideas to a potential user.

The opinion of the project managers was that participating students: (1) learned to identify and structure vaguely stated problems, (2) learned to work effectively in groups to plan and develop solutions to problems, (3) learned the importance of being able to relate to other people in order to accomplish the project activities, (4) learned to present information in an effective, clear and concise manner, and (5) developed a sense of professional maturity and a confidence in their abilities.

### 3. ENGINEERING CASES

A design project, carried through from conception to completion and operation, is excellent in (1) acquainting the student with additional dimensions and (2) in developing competency. A major difficulty, however, is that a properly executed design project requires substantial amounts of time. In a crowded curriculum, one can question the justification of allowing time for enough projects to make
the experience sufficient and worthwhile for students. Use of engineering cases is an alternative which may take less time to give a broader perspective (an awareness of differences as well as common aspects in cases used and in engineering practice). Cases allow consideration of open-ended solutions as do projects. Engineering cases provide a flexible medium for learning engineering in a realistic context.

An engineering case is a written account of an engineering activity as it actually took place. A case tells the story of a real engineering experience, quite often from the viewpoint of one or more participants. In addition, the usual case includes detailed background information such as: sketches, drawings, photographs, calculations, test results, scheduling data, production processes, budget information and other pertinent data which help the reader follow actions taken. An engineering case differs from a technical paper! Focus in a case is on how results were obtained rather than on demonstrating validity of a solution. A case often shows individuals interacting in a meaningful way to accomplish an engineering task. A case is often written in segments with each portion terminating at a critical decision point.

All cases provide opportunities to raise questions and provide answers. There is no single correct question and no single correct answer, however. Cases, like good design problems, depend on many subdivisions of engineering, often raise questions of human behaviour and ethics as well as technical questions, and permit many possible solutions. Although a case is an account of a real occurrence, the degree of realism varies and depends on the skill of the writer. Cases can vary in length from a few pages to many pages. The best cases are long enough to include some non-technical aspects (e.g. people, time constraints) yet short enough to be studied in a few hours and be discussed in a class session of one to two hours. A case can be a history, a snapshot of a situation, or a problem. All three types are useful as teaching tools.

Engineering cases provide a learning resource which can be used in various ways. How and where cases are used depends on course objectives, nature of the class, and the instructor. It should be emphasized that there is no right or wrong way to use cases, just a variety of ways to bring reality into the classroom and enhance learning through experience of others.

One effective use of cases is in class discussion. Students are assigned a case, or a portion of a case, to read. Specific question may be asked to direct student reading. An alternative is to ask them to be prepared to discuss what they find important. During class discussion, students are required to move discussion forward and explore various facets of the case. The students define problems and issues, propose solutions and courses of action, and defend their viewpoints among their peers. The discussion mode is especially useful in helping students learn about theory of design, development engineering, and professional practice, all topics which are difficult to talk about abstractly.
Case discussion can catch student attention and provide an opportunity to exercise engineering knowledge and judgement. Discussion, however, is not efficient for learning new material – that should be done through textbooks or library research. Unfortunately, most students find this very dull. Use of cases, however, can motivate students to acquire new information for a specific purpose, thus making textbook reading more appealing and rewarding.

Engineering cases can be used as a source of problems. Problems can be abstracted from a case and used as textbook type problems. One can also assign a case with a specific problem goal, thus the student must define and model his own problem.

Cases can be used as a source of design projects with realistic boundaries. For example, the project can be to design a component which is not detailed in the case, or to design an uprated or down-rated version of hardware described in the case. Such a project is put in a realistic, commercially viable context.

Cases can be used as motivation for laboratory experiments. One instructor provided students with a case describing structural failure in hopper trailers due to severe highway use. He also supplied a specimen of steel plate which he said came from the trailer. The assignment was to determine if the steel were suitable and to report the findings. The students had to decide what tests were needed, perform the tests, assess results, and write a report. It seems obvious that enthusiasm and learning were much greater than if students had simply been asked to perform laboratory tests on a plate of steel.

I have a personal preference for the case problem/discussion format. In this context, students are given the first segment of a case which includes background information, data, drawings and similar items of information. In whatever form and whatever quantity, the net result is to confront a student with a situation for which he is expected to develop a solution. The student is expected to analyze the situation, define the problem, develop possible solutions, account for all considerations (this includes an opportunity for library research), select the 'best' solution, and submit a written 'proposal' or 'solution'. When the class meets, discussion of the case can be handled in a variety of ways as indicated by Kardos (1974).

Since each engineering case is the story of an actual situation or event, the student has the benefit of seeing how various situations have been handled by real individuals in engineering practice. From time to time, a student will make it clear that he considers his solution superior to that actually given in the case. There have been times when I agreed with the student. It is little short of amazing what this can do for the individual's morale and self-esteem.

It is claimed that use of engineering cases gives students a somewhat vicarious or indirect experience. This is granted, to a degree. But it must be recognized that the student is dealing with a real situation, requiring consideration of a number of factors in addition to analysis. A good solution on the part of the student does require a lot of synthesis. Use of engineering cases is much more 'time
effective' than using projects.

In using engineering cases, students learn from examples. An aircraft failure, for example, may teach something about structures, fracture mechanics, fatigue failure, test planning, and so on. This mode of learning is not as 'neat' as the deductive mode where we might try to deduce failure events from theory of elastic continua and theory of lattice dislocations. Use of cases has advantages:

1. Case use motivates students who are more interested in application than theory. They will not become great scientists but they can become excellent engineers.

2. Case use teachers problem formulation and use of engineering judgement. Textbook problems rarely give an opportunity to exercise judgement. Extracting a simplified problem from a complex situation presented in a case requires judgement. We are all aware that good formulation of a problem makes solution easier.

3. Case use often introduces important concepts which have not yet been incorporated in textbooks.

4. Case use humanizes engineering. Engineering and design are done by real people who often make mistakes. This is rarely apparent in textbooks. In case use, students learn that making changes to correct errors is an important and accepted part of engineering practice.

5. Case use is a natural mode of learning. Engineering cases help in learning engineering in somewhat the same way as magazines and tape recordings help in learning a language.

6. Case use provides a bridge between the academic world of concentrated learning and the working world of application. Cases do not provide work experience, but they can help prepare the student for some of the shock of his first employment.

7. Case use teachers learning. The student starts with an example, for which he must find the applicable theories and knowledge for solution and learn to use these tools. This is the reverse of the textbook approach in which we first learn knowledge and then apply it. It has been said the doubling time for knowledge and information is about ten years. Certainly the ability to learn as the situation requires is essential.

4. SUMMARY

Education of students to become engineers requires more than basic physical sciences and analytical engineering sciences (at whatever level). Experience in synthesis, i.e. design, is an essential ingredient. The most effective way for a student to learn design is through the experience of design projects. Projects, however, are costly in time. Engineering cases provide a different way of giving insight into the design process, a way which requires less time and provides an opportunity to see a broader segment of the design spectrum. Projects and cases can complement and supplement each other to help students become more effective engineers.
REFERENCES


FROM UNIVERSITY TO INDUSTRY - STUDENT PARTICIPATION IN THE INNOVATION OF COMMERCIALLY VAILABLE TEXTILE MACHINERY

Prof. G.R. Wray, Mr. J.E. Baker & Dr. R. Vitols
Loughborough University of Technology
England

ABSTRACT

The Loughborough system for the education of mechanical engineers has a vital integrated sandwich pattern which involves the student throughout the four years of the course. Developments in the teaching of engineering design, over the last decade, have resulted in a considerable increase of student participation in industrially based projects. This has encouraged many instances of student innovation through design work on the various stages of industrially sponsored projects, from initial concept through to the detailed studies required in value engineering. Examples are taken of textile machines, designed and built in the Department of Mechanical Engineering, which have proved to be commercially viable.

RESUME

Le système qui prévaut à l'Université de Loughborough concernant l'éducation des étudiants de Génie Mécanique comprend un système de stages alternés intégré qui permet aux étudiants d'avoir une expérience pratique pendant toute la durée de ses études. Les progrès qui ont été faits au cours des dix dernières années dans l'enseignement du dessin industriel ont entraîné un accroissement considérable du nombre d'étudiants participant à des projets de recherche parrainés par l'industrie. Ceci a entraîné plusieurs innovations faites par nos étudiants réalisées lors d'études décrivant les différents aspects de projets de recherche, ces dernières sont menées depuis l'ébauche jusqu'aux études, détaillées nécessaires à la construction mécanique de haute qualité. On peut trouver certains exemples dans les machines textiles conçues et construites par le Département de Mécanique Industrielle et qui se sont avérées rentables sur le plan commercial.

ZUSAMMENFASSUNG

Zu dem Loughborough System für die Ausbildung von Maschinenbauingenieuren gehört ein wichtiger praktischer Kurs, der als Ergänzung des theoretischen Kurses gedacht ist, und der parallel zu diesem auch die ganzen vier Jahre hindurch läuft. Das Lehren von technischen
Entwürfen hat sich in den letzten zehn Jahren in praktischer Hinsicht so entwickelt, daß mehr und mehr Studenten an industriellen Projekten teilnehmen. Das Resultat dieses Trends war, daß Studenten sich nicht nur an von der Industrie finanzierten Projekten beteiligten, sondern sehr oft auch direkt für Erneuerungen und neue Entwürfe verantwortlich waren, und zwar vom Anfangsstadium bis zum Endprodukt, inklusive der präzisen Forschung, die während der Entwicklung eines Entwurfes verlangt wird. Als Beispiele werden Textilmaschinen, die in der Maschinenbauabteilung entworfen und produziert worden sind, und die sich als kostengünstig erwiesen haben, angegeben.

1. THE INTEGRATED THIN-SANDWICH COURSE

An important change in the pattern of engineering education in the Department of Mechanical Engineering at Loughborough University of Technology, over the last few years, has been a steady increase of student involvement in industrially based projects. The underlying strategy for such academic/industrial collaboration has been the integrated thin-sandwich pattern of the mechanical engineering course, which has been operating for more than 20 years. Coupled with this approach to the education of engineering undergraduates has been developments in the teaching of engineering design. Previous industrial experience and current research interests of the academic staff have enabled the Department to tackle industrially sponsored projects with confidence, and to involve the students in the work through project activities, thus enlarging and developing their innovative and entrepreneurial experience.

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*Fig. 1. Pattern of the integrated thin-sandwich course*
Fig 1 shows the sandwich pattern of the four-year mechanical engineering course, where the three academic years are denoted as Parts A, B and C. It will be noted that the students spend over 60 weeks on structured professional training periods suitably interspersed with the academic terms to provide planned industrial experience at appropriate educational stages. The importance attached to this practical aspect of the course can be emphasised by the fact that 25% of the marks contributing to the final degree award are attributed to such training. Several methods are used to accrue the marks attained, including day-to-day assessment on the job, a continuous written record of the training, a written examination on completion of period 1, a dissertation during period 3, and an oral presentation to a panel of assessors after period 5.

It is preferable that students commence the course with the support of an industrial sponsor who will provide training. However, this is not essential, as the University is excellently equipped with workshop facilities and training staff which can meet all the basic training requirements. Periods 1 & 2 cover basic processes, 3 and 4 are spent in technical departments such as planning, drawing offices and quality control, whilst in period 5 the student undertakes a project or assignment suggested by his Company. It is Departmental policy to assist every student in finding a place in industry for period 5.

2. INNOVATION AND THE TEACHING OF ENGINEERING DESIGN

In the first week of the Part A academic programme, students are introduced to design by means of a model problem, involving each person in a small scale make-and-test exercise as described by Baker (1978). The number of students commencing the course is normally 85, which means that the manufacture of real hardware, even for a relatively small project, cannot be contemplated. Consequently, other first year design projects are only taken to the paper stage to enable an overall view of mechanical engineering to be maintained, along with application of engineering drawing and any relevant analysis covered in the first year subjects.

Engineering design forms an important part of the second academic year (Part B). A study of machine elements, such as gears, bearings and springs, forms the major subject material and includes a detail design project where many of these elements are applied. The traditional power transmission system problem has many aspects in its favour and is often used as assessed coursework. However, the conceptual aspect of design is not overlooked and a project of this nature is also undertaken, this often being based on a known industrial requirement, as exemplified in the gauge-changing unit in Section 3. Again, due to the number of students, such project work in Part B is restricted to sketches, assembly drawings and detail drawings of component parts and relevant analysis.

At Part C, every student is given a final-year project, which is highly rated towards his/her degree. Each member of the academic
staff supervises 3 or 4 projects annually, which means that both the subject and the nature of problems set to the student varies widely. Many of the projects are related to the research and industrially sponsored work of the particular member of staff, and in consequence are of a design and/or experimental nature. It will be noted, from Fig 1, that all the students have completed their professional training by this time which, along with a good analytical basis formed in Part B of the course, gives the staff the assurance that most students will approach their project work with confidence. Students are permitted a choice of subjects in the final year so that they can slant their course towards their developing interests. Engineering Design is a typical 'elective' subject taken by about one-third of the students. A broad-based lecture programme, from 'design methodology' to 'quality and reliability', and covering such topics as ergonomics and optimisation, supports group design projects which form a large part of the assessment in the subject. Each student works within a group of three on a major project and with two other students on a value engineering exercise. Many of the design projects come from industrial enquiries and have become an excellent method by which industrial contact can be initiated and, in some cases, have led to further work; they provide an opportunity for the students to investigate live problems and develop their innovative abilities knowing that the solutions are likely to be of real value. This often applies to the individual final-year projects referred to above and it is to be noted how motivation increases when students become aware that they are conducting exercises which have more than academic value.

The Department has an excellently equipped workshop with requisite technician staffing which, although severely pressed at times, means that it is possible to manufacture components for projects which require hardware, although there has to be a financial limitation in cases where industrial sponsorship is not available. From the student viewpoint, planning of the work so that it will be available in time for testing, along with care in detail design, is vital and invaluable experience.

3. TYPICAL EXAMPLES OF INNOVATION AND ENTREPRENEURSHIP

Fig 2 indicates how a small team of academic staff has encouraged some 160 undergraduates and 21 postgraduates to contribute to the research, design and development of various novel textile machines, several of which have culminated in commercial exploitation. Two recent cases, shown on this flow-chart, concern the entrepreneurial activities of a knitwear manufacturer (Corah) who commissioned the University Department in 1978 to design and build a prototype automatic rib transfer machine (Fig 3) based on previously conducted sponsored research in the Department, and a gauge-changing machine in 1980; both machines are currently at the production stage having gone through extensive field trials as described in Knitting International (1982). At the time that the detail design of the
Fig. 2. Flow-chart - Textile Machinery R & D at Loughborough University of Technology
Fig. 3. The Prototype Loughborough ART Machine  (Corah Limited, 1980)

Fig. 4. The Loughborough Gauge-Changing Machine  (Corah Limited, 1981)
gauge-changing machine (Fig 4) was underway, this project was set to the Part B students, specified as a general need, requesting them to sketch a conceptual solution with appropriate analysis. It was interesting to note that, of the 70 students given the problem, only 3 came up with a solution similar to the actual machine, whereas at least 8 other distinct concepts were proposed. Whilst the machine was being built, the Part C students were required to carry out a value engineering exercise on its design. It is emphasised that, whilst the industrial company sponsoring the two prototype machines has based its decision on experimental rigs which had been designed by a postgraduate research worker, he in turn had developed his ideas from initial concepts proposed by earlier undergraduates.

One of the first examples of this latter approach was the Locstitch pile-fabric machine, s-e Wray (1976). This University innovation, shown in Fig. 5, has achieved world-wide application. Two members of the academic staff, Professor G.R. Wray and Mr. G.F. Ward, conceived a novel locked loop pile-fabric which could be made at potentially

![Fig. 5. The Loughborough Locstitch Machine (Pickering Limited, 1981)](image-url)
high speeds by a sewing/knitting technique (Fig 6). Whilst the inventors were seeking government and industrial support for the development of their ideas in 1967 undergraduates commenced initial investigations through project work. A ten-times scale wooden model of the needle arrangement was built by an undergraduate who produced an animated film which illustrated the basic principles in slow motion and also provided the first tangible evidence that the fabric was feasible as a practicable manufacturing proposition. Further student project work on a combined graphical and spatial study, using large scale models (Fig 7), led to the employment in 1968 of one of the authors (Dr. R. Vitois) on government sponsored research, from which the University designed prototype machine was developed in 1971 in co-operation with a specially formed company, Pickering Locstitch Ltd. Undergraduate participation in the work continued throughout this period; Fig 8 shows one project whereby the student produced an actual-size Meccano-type model to compare the kinematic and dynamic...
characteristics of the needle-bank actuating linkages with his theoretical computer-based studies.

Around the time of the Locstitch project, the teaching of engineering design was expanding and the subject was brought into the final year as an elective. From that period, there has been a gradual change in emphasis in that student projects have become a method by which industrial problems are first investigated. Students are able to visit the industrial organisation to discuss the problem with the technical staff directly involved, and their final reports are submitted to the company for evaluation after the academic year has finished. Value engineering exercises are conducted not only on the prototype machines whilst they are being constructed in the Departmental workshops, but also on first production machines which undergo commissioning in local industry. This academic-industrial
collaboration enables lectures and case studies to be presented in the light of first-hand on-going experience. Such presentations highlight technological and managerial procedures. Moreover they emphasise the product and process economics, together with their social implications, against the background of a real competitive environment. Co-operation of this kind has been excellent and has led to further support, often with hardware, and sometimes to sponsored work at postgraduate research level. Undoubtedly the contribution made by undergraduate students has proved invaluable to the furtherance of several commercial products. From the education viewpoint their involvement has enabled them to become more effective in innovative and entrepreneurial activities.

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ACKNOWLEDGEMENTS

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SMALL GROUP DISCUSSION ON POLITICAL ASPECTS OF INNOVATION
INNOVATORS ARE A BLOODY NUISANCE

Discussion paper by chairman/convenor
Geoff Beuret
Great Britain

Educators tend to see innovation as intrinsically desirable because it can lead to new products and processes, increase market shares, maintain competitiveness etc. Hence, it is argued, we should equip our young engineers for innovation and entrepreneurial activity. But to do this effectively we need to consider the context of the innovation - the place of innovation per se in the innovative and entrepreneurial process.

Many innovations fail because they are technically inappropriate or unsound. But many others, perhaps more, fail because there are those who believe that their interests are best served, at least in the short term, by the suppression of an innovation. This can happen within an engineering department, within an organisation, at industry and at national and international level.

A new idea may threaten the reputation for innovation of more senior engineers within a department. It may employ technology with which older engineers are not familiar. Again, there may be opposition to an innovation because other departments perceive it as a threat to their position within the organisation. These departments may be able to subvert the innovation by exaggerating cost or materials supply or production problems. They may be able to persuade a technically ignorant management that lower R&D costs, longer production runs and easier capital depreciation will flow from a more conservative technical policy - and they may, of course, be right.

If the organisation is large and powerful it may be able to suppress innovation by buying out innovative competitors and patents, by distorting markets etc. It can be argued that the development and introduction of aluminium and plastic bodies for motor cars, renewable energy supply and energy conservation technologies, recyclable packaging and cold water detergents have all been delayed because these innovations threaten powerful interests. These tendencies are reinforced by monopolistic or oligopolistic markets and by high entry prices to newcomers.

And, last but not least, the suppression of innovation offers the prospect of a peaceful and comfortable existence to those who are doing well out of the status quo, even if it is in their long-term interest to innovate.

It seems sensible, therefore, to acquaint the young engineer with these facts and to equip him or her as best as we can with the abilities to argue and to persuade, to understand something of
costing and the broader business context, to play the political game within the department or organisation etc.

On the other hand there is the argument that these things cannot be taught and/or that it would take too long to do so or that they are not the concern of engineering educators.

The aim of this small group is to discuss these ideas and their consequences for engineering education.
The ever increasing demand for new sources of petroleum will mean an increasing demand for offshore oil and gas production; the demand for new mineral supplies may be less urgent but will nevertheless before long require more attention.

Severe environmental conditions, marginal field conditions, deep water, enhanced recovery, they all will require more effort from the engineer than before. It is therefore evident that in the near future the number of engineers required by the Offshore industry will increase.

First of all we have to come to an agreement which activities of offshore engineering we want to discuss. I would suggest that we concentrate on those engineering activities applied by the industry for their offshore operations above the seafloor, be it for exploration and production of oil or gas, minerals or renewable energy.

For those activities a general division can be made of the related aspects such as

- Ocean Environment
- Process technology
- Topside facilities
- Marine structures
- Underwater technology

These aspects are covered by various university departments and even within these departments a large number of sub-faculties are involved.

What is the best study programme for students who may wish to start their professional career in offshore engineering?

Independent of the overall study framework of the university concerned, the following two statements could be discussed:

a. The prime requirement is for professional engineers, trained and skilled in their chosen branch of the profession, but with extensive and continuing experience of the effect of the marine environment on their works (the specialist), or:

b. The prime requirement is for professional engineers trained and skilled - but to a limited extent - in most of the many aspects related to marine structures (the generalist).
It is suggested that the discussion concentrates on:

- Definition of offshore engineering
- Philosophy of study framework
- University courses offered to the future offshore engineer
- Subjects included in those courses
- Future need of industry for offshore engineers.
SMALL GROUP DISCUSSION ON HYDRAULICS

Discussion paper by chairman/convenor
M. de Vries, Delft University of Technology
The Netherlands

Hydraulics can be defined as applied hydrodynamics.

Engineering applications:
- Mechanical engineering (e.g. hydraulic machinery offshore)
- Naval architecture
- Civil engineering - sanitary engineering
  - hydraulic eng. & watermanagement
  - river engineering
  - coastal eng. (incl. offshore
  - irrigation & drainage
  - hydropower

Research for civil engineering applications of hydraulics:
- refinement of knowledge, necessary in following fields
  - mobile bed river- and coastal-morphology
  - waves coastal-morphology, offshore structures
  - density currents watermanagement - environmental hydraulics
- refinement in experimental hydraulics (study of hydraulic processes in laboratory and field, hydraulic scale models)
- refinement in computational hydraulics

Educational needs for civil engineering applications:
Stage 1 (all civil students). Sound basic knowledge of fluid mechanics with special reference to practical applications to civil engineering problems
Stage 2 Additional training for students in hydraulic engineering watermanagement and sanitary engineering. Background for specialization in these fields.
Stage 3 Specialization in fluid mechanics for civil engineering (experimental, theoretical & computational).
Stage 4 Research training

N.B. Basic training (stage 1) in hydraulics can only be obtained if the course includes some laboratory experiments.
Reading, whereby the designer of the product has discussed with the students his company's marketing policy and its approach to value engineering, manufacture and cost.

A special laboratory for process equipment has been established at the Delft University of Technology, which enables the marketing and economic aspects of engineering product development, as well as research and development activities, to be linked to the education of students.

At Napier College a course specifically dealing with innovation and entrepreneurship has been devised in which case study material is incorporated to show unsuccessful as well as successful ventures.

The inherent difficulties and lessons learned from bringing case studies into teaching is highlighted by design project experience at the University of Detroit. Such case studies have involved subdivisions of engineering and have raised questions of human behaviour and ethics as well as being concerned with technical matters.

The wide variety of case studies to be presented in this session should therefore provide the basis for much useful discussion. The following questions might usefully be considered:

1. What is innovation? What is entrepreneurship? What are the conditions for cooperation of an academic institution with an existing industrial company? What are the circumstances whereby entrepreneurial activity, eg to the point of forming new companies, might be demanded from the academic institution for the development of a university-inspired innovation?

2. How can innovation and entrepreneurship be conveyed to engineering students? Can it be "taught" or is it to be "caught"? Should the students and academic staff be directly involved in the actual innovation of new products and processes?

3. What are the values of case studies in engineering education? Should they be taught by people who have experienced innovation and entrepreneurship at "first-hand", or is it possible to teach them "second-hand", ie based on other people's experiences?

4. From the particular case studies presented in this session what can be learned regarding the education of the engineer for innovative and entrepreneurial activity? Has there been a common theme to the different experiences described in the various papers?

5. Should a distinction continue to be made between the conventional teaching of fundamental subjects such as mathematics, mechanics, fluid dynamics, etc., and the application of these fundamentals in engineering? Are there other ways than case studies for educating the student engineer towards the real needs of industry for new and improved products and processes?
The following projects have been completed by the SEFI Working Group on Curriculum Development or are under way:

- Establish a methodology of curriculum design
- Organise seminars on specific subjects of engineering curricula.
  - 1980 Erlangen: Industrial/technological change in electronic engineering
  - 1981 Compiègne: Industrial design and the training of engineers
  - 1982 Undine: The impact of electronics and computers on the training of mechanical and industrial engineers
  - 1983 Basel: Safety education in engineering curricula

The results of the seminars are published in monographs available to all SEFI members.

- Establish a database on engineering education, called SEFINFORM (now 1000 entries).
- Analyze typical engineering curricula by means of a mini-survey (now under way).

"Engineering curricula for the year 2001" will be the main theme of the future activity of the working group. The members of the working group will be present in Delft and expect to get ideas from the participants by discussing three specific problems with them:

1) The changing pattern of society and industry and its demand upon the engineering profession
2) Fields of increasing importance (and new fields).
   Fields of decreasing importance
3) The engineer: specialist or generalist?
SMALL GROUP DISCUSSION ON MATHEMATICS

Discussion paper by chairmen/convenors
D.J.G. James and K. Spies
Great Britain/BRD

During discussions at the SEFI Conference held in Brighton in 1981 an agreed programme of work for the Group was outlined and being directed towards two objectives:

a) identify problems associated with transition from school level mathematics to those encountered in the first year of an engineering undergraduate course and to investigate possible remedies;
b) attempt to determine an agreed core content for the mathematics element of an engineering course (concentrating initially on Mechanical, Electrical and Civil Engineering).

This work is now in progress with the initial programme being of a pilot nature and involving an investigation of the current situation in a restricted, though representative, number of institutions in each of the participating countries. The investigation at each country follows a common pattern and is based on a number of specified questionnaires. All working members have been asked to prepare a report which will form the basis of the discussion papers at the conference.

During the conference, discussion consideration will also be given to the question "How best to make the preliminary findings available on a wider scale?" so that a comprehensive report of the current situation in relation to a) and b) can be produced during the following year. Possible future areas of investigation will be considered; amongst those already suggested are:

(i) Computing and the mathematics curriculum
(ii) How should mathematics be presented to engineering students
(iii) Continuing education in mathematics for engineers

Anyone wishing to have a specific matter discussed at one of the sessions is asked to submit details to one of the Convenors prior to the Conference so that adequate preparation can be made. The Convenors will also be pleased to send details of the Group's current programme of work to conference delegates unfamiliar with its work and who wish to participate in the discussion sessions.
"The increasing use of computer programmes in engineering practice means that engineering teaching should include instruction in the use of such programs (see European Journal of Eng. Education 3, 233 (1978)). Obtaining suitable teaching computer programmes for all the branches of engineering is a difficult task, which can be alleviated by exchange of computer programs between universities. Such exchanges may be developed as a service within the framework of a Working Group of SEFI and the Council of SEFI is at present examining the feasibility of such a project".

(SEFI News).

The objective of the discussion group No. 13 on Computer Programs for Engineering Education is to examine whether such a SEFI computer program project should be undertaken. Such a proposal throws up a number of questions:

- Should CAD methods be part of an engineering students' training and therefore be part of normal curricula, or should student education be confined to principles, leaving the appreciation of CAD to his later industrial experience?
- If it is agreed that he should be introduced to the CAD as a student, how is the problem of obtaining good software to be solved?
  . Should each department over the years develop its own?
  . Are there sufficient suitable programs available at universities, or is it necessary to buy industrial programs?
  . Should personal contact between staff of the different schools be used to obtain individual software exchanges?
  . Should some centralized exchange system be organized?

Whereas for personal exchanges of programmes, inadequately tested, non-standard, ill-documented programs are tolerable; the inauguration of a centralized distribution system brings with it a responsibility that the programs distributed correspond to some minimum level of standardisation and documentation.

A centralized system must also have a small management body to select the appropriate programs, and some arrangement whereby potentially good programs are brought up to acceptable levels and distributed. Can suitable people for such a small management body be found? What methods are available to carry out the required work?
Before SEFI can commit its funds to a computer project working group, all these points should be thoroughly discussed and general agreement found that it is an area where some form of organisation is necessary and SEFI is in a position to provide this organisation.

This discussion group has a very clear remit and the consequence of the group's decision could contribute much to the future education of European Engineers. Those symposium delegates interested in this area are therefore urged to contribute to the discussion.
Poster Presentations

A restricted number of authors will prepare a poster on the subject of their papers. This implies that the authors will present the essentials of their papers on boards to be displayed in the lobbies of the Aula Centre during the Conference.

In order to enable the Conference participants to examine these contributions in advance, the papers concerned are included in this Conference publication.
THE "FRONTIER-ENGINEERING": THEIR CONNECTION WITH THE INNOVATION AND
THE PROBLEMS OF THE EDUCATION

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ABSTRACT

It is well known that during the last decade, beside the traditional engineering centred within the civil-mechanical-electrical triangle, a new set of innovating engineerings gradually developed, whose cultural framework is already well defined and consolidated (such as the electronic engineering, the nuclear engineering the aerospatial engineering and so on).

What's more, several scientific and technological researches, pushed by physical-chemical-mathematical ones, the biological-medical ones and the environmental-economical-social ones, giving rise to more or less defined new "engineerings", such as the municipal engineering, the biomedical engineering and the "new energies" engineering.

Two tendencies are appearing in the field of the engineering: the first one, for which the innovation derives from a scientific technological development arising in a well consolidated cultural framework; the second one, which, on the basis of an advanced scientific research, is pressing on old and sometimes fantastic frontiers, giving rise to innovating processes that have such a strong fall-out on the technological and social context as to push towards the creation of new established "engineering".

This continuously developing process has an immediate correspondence in the education of engineers. Therefore, even within the University, two tendencies appear: one, which tends to utilize the fall-out of the scientific research in the traditional fields and tries to insert them in a cultural framework, carrying out a sort of "cultural maintenance"; the second one, which must have the sensitivity to favour the development of that scientific research for which the innovation appears sometime in a singular way and which could give rise in the near future to great poles of innovation.

In the latter case, the connection with the education is surely more complex.

This note is intended to analyze the above mentioned problems in connection with the Italian situation, trying to deduce some general and methodological observations.
EDUCATION FOR A GREATER APPRECIATION OF INDUSTRIAL PRACTICE

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ABSTRACT

Any engineering graduate can only contribute fully to company activities if he has an awareness of industrial organisation and structure. As well as technical knowledge, study of engineering management, project planning and product innovation enhances his industrial role. A curriculum to meet the requirements of students on B.Sc. and M.Eng. courses is described, which aims to educate first-class engineers who can readily apply their knowledge to industrial requirements. The need for close liaison between universities and industry in course planning and conduct is stressed.

RESUME

Un ingénieur diplômé de l'Université ne peut participer pleinement aux activités de la société qui l'emploie que s'il s'est familiarisé avec les rouages et l'organisation de l'entreprise. En effet, le rôle qu'il peut-être appelé à jouer à titre de cadre dépend non seulement de ses compétences techniques, mais aussi de ses connaissances en gestion appliquée à l'engineering (par exemple planification des projets, recherche de produits nouveaux, etc.). Nous présentons un programme adapté aux besoins d'étudiants préparant une licence scientifique ou une maîtrise d'ingénieur; les activités décrites visent à former d'excellents experts techniques pouvant satisfaire aux exigences de l'industrie par une rapide mise en application de leurs connaissances. Nous mettons l'accent sur la nécessité d'une liaison étroite entre les universités et l'industrie pour la création et la réalisation de ce programme d'études.

ZUSAMMENFASSUNG

Ein Diplomingenieur kann nur dann voll zu den Aktivitäten seines Betriebes beitragen, wenn er eine gewisse Kenntnis von industrieller Organisation und ihrer Struktur besitzt. Nicht nur technisches Wissen, sondern auch Kenntnisse im Management des Ingenieurwesens, in der Projektplanung und der Neueinführung von Produkten sind für
1. INTRODUCTION

Innovation is an inherent ability which must be nurtured in a suitable environment to flourish. Entrepreneurship can be learned, but only via an intimate awareness of industrial activities and structure. Industrial engineering, as practised by designers and technologists must feature more prominently in university curricula. Efforts should be made to develop appropriate ways to treat the non-technical material which grows in importance with career development. Such taught courses can ease the transition from directed study to the real-life world and assist with the furtherance of innovative and entrepreneurial skills.

Examples of topics which assume increasing importance during an engineering career are: the management of engineering, product/project planning and organisation, management and manpower considerations, economics, finance and marketing, product innovation and support.

University staff must themselves be aware of industrial practice if they are to develop a successful course, so strong links with industry and research organisations are essential. A knowledge of job patterns of young graduates as they assume responsibility, and of the realistic academic provision of industrial needs for the next generation of designers, is necessary. The teaching of industrial engineering must be relevant and applicable within the context of a technological education. The aim of the course must be the education of better engineers who can apply their knowledge and abilities to industrial requirements, rather than to produce ill-equipped instant managers. An opportunity to practise skills in industry, as well as via university based project work, must be an integral part of the course.

In this paper, the design of a curriculum to meet the needs of students on the B.Sc. and new M.Eng. courses in Electronic and Electrical Engineering at the University of Surrey, will be described, with reference to points made in this introduction.
2. THE UNDERGRADUATE COURSES

The aim of any engineering course should be the education of students such that, on graduation, they are quickly able to assume effective roles in industry, research organisations or allied areas of employment. Graduates should be equipped to contribute actively in both the short and long term. The former is achieved by a knowledge of present day science and technology, the latter by a familiarity with the fundamental scientific principles and engineering practice relevant to the subject area of a chosen career. These rather erudite objectives are easy to state but more difficult to fulfill. However, over many years a B.Sc. course has been developed, of four years' duration including a twelve month period of industrial training, which largely meets the stated aims. The course is well recognised by schools and colleges, as judged by the number and quality of applicants, and by industry since most students, even in these recessionary times, are receiving suitable offers of employment.

In October 1981, a second undergraduate course leading to the degree of Master of Engineering (M.Eng.) was instituted. The object is to produce a number of graduates of high academic and technical competence who have a greater appreciation of industrial aspects of engineering than is possible in B.Sc. courses. The M.Eng. has been designed specifically for students who are prepared to commit themselves to an industrial career from the outset and is of 4½ years' duration - 11 academic terms and 4 periods of industrial training amounting to a total of 74 weeks. If one includes this vacation training, the course is equivalent to a conventional course of considerably more than five years. In view of its length as well as

Diagram 1.

The B.Sc. course

The M.Eng. course
breadth of treatment, the course warrants the award of a higher
degree, that of a Master.

It is anticipated that, in the steady state, some 25% of the
total undergraduate intake will take the enhanced M.Eng. course.
The overall framework of the two courses is shown in Diagram 1.

3. ACADEMIC CONTENT OF THE COURSES

As the course titles suggest, they cover a wide range of sub-
jects, concentrating on electronic circuits and systems, including
telecommunications, digital techniques, microprocessors and micro-
electronics, but also ranging from device physics and technology to
electrical machines and power generation. Ultimately, students will
want to specialise in one of these fields but we believe that a
choice of specialisation should be made after a thorough foundation
in all the major branches of electronic and electrical engineering,
together with the relevant facets of physics, mathematics, materi-
als science and mechanical engineering.

A broad basis is taught and developed during the first two
years of the course. This is the core which is considered essential
for all students. In the final year of the B.Sc., students are able
to concentrate on a number of selected options from a list which
encompasses the full range of electrical and electronic specialisms.
At present 6 can be chosen from a list of 11. Since the academic
aims of the B.Sc. and M.Eng. coincide in the early stages, there is
much common ground during the first two years. The third academic
year will see a major separation of the two courses, although some
topics will be common. The choice of subjects will be restricted
for M.Eng. students, so retaining the breadth of study to a later
stage of the course.

The final three terms of study in the M.Eng. course will allow
the M.Eng. students to go very deeply into two subjects of their
own, and their companies', interests and requirements. These disci-
plines will be taken to a level at or beyond the M.Sc. course
modules currently offered by the Department in Automatic Control,
Computers and Microprocessors, Microelectronics and Telecommunica-
tions. The M.Eng. will be enhanced by an industrial engineering
course, as described in a subsequent section.

All courses are backed up by tutorial sessions and laboratory
work. Small group tutorials feature in each stage of the course.
Students attend tutorials twice each week, this providing an excel-
 lent opportunity for general discussion and for dealing with prob-
lems which may arise from material covered in lectures. Computer
programming is learned at an early stage and a first year course is
provided in communication skills which assists students in the
development of verbal and written skills, so important in their
later careers. Practical work in the first year forms an important
complement to material covered in lectures and takes the form of
standard experiments and small constructional projects. In the second year, these relatively straightforward experiments give way to the more open-ended type with a significant design content. Practical work in later years is very different as all students will, by then, have had some experience of industrial development work and are ready to become involved with technically demanding projects. These are of two types - mini-projects on which small groups work for, typically, about 36 laboratory hours, and major projects which B.Sc. students work on full-time for almost a whole term. M.Eng. students will perform their major project as part of their final industrial training period. Laboratory performance contributes towards stage assessment and project marks are included in the degree award.

Professional engineering studies feature much more prominently in the M.Eng. course. This is achieved by virtue of the fact that (i) lecture courses on industrial aspects of engineering are included throughout, (ii) students attend courses on engineering practice in the first two years, and (iii) industrial training periods are closely integrated into the course. The following section will examine these three points in more detail.

4. PROFESSIONAL ENGINEERING STUDIES

a. Industrial engineering

This describes a theme that runs throughout the M.Eng. course, its aims being to create an awareness of industrial methods, examine the skills needed by practising engineers, consider the role of engineering in the national scene, and integrate the academic and industrial aspects of the course. The course will include lectures, talks by visiting industrialists, group seminars, case studies and relevant exercises. It is envisaged that students will derive greater benefit from the course after some industrial experience, so the topic appears in the first year only as a two-week full-time course immediately before the first industrial period. The content will cover industrial organisation and processes related to the production of electronic devices and equipment. In Year 2 the course will continue throughout the session followed by a further short intensive block. Then, a more advanced treatment of manufacturing processes and materials will be given, together with an introduction to design methods, development planning, activity scheduling, cost estimating and cost control. The third year will include design methods of specific relevance to electronic systems, including computer-aided-design, system and layout design and testing, aspects of reliability, quality assurance, economics of product development, costs and cash flow. The final year will cover more advanced CAD and computer-aided-manufacture, case studies of product and project design and implementation through to service, product life-cycles
and life-cycle costing, automated testing, decision making, innovation, marketing and sales promotions and product documentation.

It is difficult, in a short paper, to do more than outline the industrial engineering course, but to suggest its flavour, a typical first year group exercise is quoted: 'You are the British engineering team responsible for setting up a factory to manufacture a cassette recorder. To suit EEC requirements, the main electronics board must be redesigned to replace several components by two integrated circuits which, it is alleged, will improve performance. This has not yet been verified. The recorder must also be modified to provide an extra socket for use with a home computer. You are to produce a plan, timetable and budget for the development, the equipping of a factory, and the production of 10,000 recorders as soon as possible'.

b. Engineering practice

All M.Eng. students will attend this specially designed EP1 course of 4 hours per week for 20 weeks in each of the first two years. This has been developed in conjunction with the local technical college who can offer hands-on experience of equipment and offer lecture-demonstrations of shaping, joining, fabrication, etc. ..., of metals and plastics, workshop practice, assembly of electronic circuits and printed circuit board manufacture. To complete the course a project is performed on the design of a component or part as specified by an industrial company, which involves the construction of appropriate models and drawings, costing, manufacture, assembly and test.

c. Industrial training

This has been a feature of the B.Sc. course for many years. The scheme is flexible, partly by design but also because of the wide range of industrial companies used. Over the last decade, some 95 companies and government establishments have offered training facilities, resulting in a variety of attitudes towards industrial year students. In particular, some firms insist that students undergo a considerable amount of formal training, while others are interested only in having students do project based work. As industrial sponsorship is not necessary for the B.Sc. course, the Department organises the placement and matches the interests of the student to the training offered by the firm. Satisfactory completion of industrial training is rewarded in the case of B.Sc. students by an additional certificate, rather than contributing to the degree classification.

With the more structured M.Eng. course, it is possible to define objectives and produce schedules for each industrial period. Sponsorship, with its associated commitments and obligations, is essential and programmes are agreed with sponsoring companies at the
beginning of the course. In the two weeks immediately prior to the start of the first academic stage, students attend a 2-day pre-induction course at the university, followed by an 8-day induction into their company. This allows them an opportunity to become familiar with company organisation, product range and production processes. At the end of Year 1 an initial 10-week training period will involve working with, and observing, general manufacturing and production processes, stages of product and prototype assembly and further familiarisation with company structure and organisation. The second 10-week session, which occurs at the end of Year 2 completes the basic training by covering development and production planning, project management, production control, marketing, sales and quality assurance as well as offering a more detailed exposure to company activities. From the topics listed, it is obvious that there is considerable cross-relating of industrial training and the industrial engineering course.

Later M.Eng. training periods are longer and involve more project work which is directly related to the company's products and special interests. Placements would cover those areas not already experienced, or more detailed attachments to groups with which some association already exists. Typical projects would be in advanced design methods, advanced manufacturing techniques, project planning or some aspect of research and development.

Unlike the B.Sc., the M.Eng. industrial training counts towards the degree, so each period is jointly assessed by university and industrial supervisors. The three industrial/professional engineering topics contribute some 20% of the final assessment.

5. IN CONCLUSION

As well as their normal lecturing, tutoring and laboratory duties, university staff who become closely involved with the M.Eng. course must familiarise themselves with all industrial course aspects if they are to ensure full integration and convince students and industry of the value of the enhanced course. This is expensive in time and effort. Industrial staff will need to visit the university to discuss course development and undertake the supervision of students while at the company. Programmes must be arranged and monitored carefully to ensure that students derive maximum benefit from each stage. It will be the dual responsibility of industrial supervisors and university tutors to direct the student's development via the twin intellectual challenges of theory and practice. The sponsoring company must ensure that a suitable, assessable project be found in the final training period, in which the student's contribution can be precisely defined, even if it is a part of a larger, on-going company activity. This all puts a further strain on the often already stretched resources of industry.

As well integrated enhanced course requires considerable effort
from industrial and university staff in terms of planning and course execution. Such an investment is necessary to achieve the objective of producing graduates with a greater appreciation of industry and industrial practice, greater design experience and higher academic standard. It is not the intention to produce graduates of any particular type, such as potential managers. Indeed, we believe that, depending upon a student's inclination during his last two industrial placements and the subjects studied at university during the final year, graduates will have interests ranging from research and design to marketing and production. Whatever the student's eventual career, we are keen to produce very good engineers, many of whom will have the entrepreneurial skill to organise high level industrial projects and lead a high calibre engineering team shortly after graduation.
ABSTRACT

The transfer of technology between university and industry must not become a 'one way street'. Therefore it is necessary to build up a circular process of a mutual transfer, which consists of four levels in one model: 
- The personal level consisting of the exchange of university teachers, assistants and students between university and industry. 
- The level of research not only consisting of fundamental research but also of smaller projects of development. 
- The educational level taking into consideration the wishes of the industrial engineers and reflecting these wishes in the university education. 
- The know-how level overlapping the other levels and in which the demands of the other levels are integrated, developed and transmitted.

RESUME

Le transfer de la technologie ne doit pas devenir de 'rue à sens unique'. C'est pourquoi il est nécessaire de construire un procédé circulaire du transfert mutuel qui comprend quatre domaines dans un seul modèle: 
- Le domaine personnel comprenant l'échange des professeurs de faculté, des assistants et des étudiants entre l'université et l'industrie. 
- Le domaine de recherche contenant ne pas seulement l'exploration fondamentale mais aussi de petits projets de développement. 
- Le domaine d'éducation où on considère les souhaits des ingénieurs venant de l'industrie et qui sont reflétés où l'enseignement universitaire. 
- Le domaine du 'know-how' qui superpose les autres domaines et où les besoins des autres domaines sont intégrés, développés et transmis.

ZUSAMMENFASSUNG

Der Technologietransfer zwischen Hochschule und Industrie darf keine 'Einbahnstrasse' werden. Deshalb ist es notwendig, einen
Kreisprozess des wechselseitigen Transfers aufzubauen, der vier Ebenen in einem Modell umfasst:
- Die personelle Ebene, die den Austausch von Hochschullehrern, Assistenten und Studenten zwischen Hochschule und Universität umfasst.
- Die Forschungsebene, die nicht nur die Erforschung der Grundlagen, sondern auch kleinere Entwicklungsvorhaben beinhaltet.
- Die Bildungsebene, in der die Ansprüche der Ingenieure aus der Praxis berücksichtigt werden und diese im Hochschulunterricht reflektiert werden.
- Die Know-how-Ebene, die den anderen Ebenen überlagert ist, und in der die Bedürfnisse der anderen Ebenen aufgenommen, verarbeitet, weiterentwickelt und weitergegeben werden.

Bild 1: Kreisprozesse
0. EINLEITUNG


1. PERSONELLE EBENE

In den technischen Disziplinen der Hochschule sollte der Aufbau des wissenschaftlichen Personals (Hochschullehrer und Assistenten) aus der Hochschule selbst heraus vermieden werden. Die Folge eines derartigen Aufbaus wäre ein sogenannter 'Elfenbeinturm' der Wissenschaft. Wenn möglich, sollten Hochschullehrer und Assistenten über den Weg der Industrie zur Hochschule zurückkommen, um somit die Forschung und Lehre befruchten zu können.

Während der Tätigkeit in der Industrie können somit zukünftige Hochschullehrer und Assistenten erfahren, welche Anforderungen die Industrie in dem jeweiligen Tätigkeitsbereich stellt; welche Kenntnisse und Fähigkeiten erforderlich sind. Obwohl zahlreiche Untersuchungen zur Erfassung dieser Anforderungen, Kenntnisse und Fähigkeiten durchgeführt wurden, können sie die persönliche Erfahrung nicht ersetzen.


Eine Erweiterung kann diese Ebene dadurch erfahren, dass auch Studenten in sogenannten Praxissemestern frühzeitige Industrieerfahrung und Erkenntnisse zu den Tätigkeitsfeldern der Industrie sammeln. In den Kruzzeitstudiengängen der Fachhochschule wird dies in Form von zwei Praxissemestern zum Teil schon durchgeführt.

Der Erfolg oder Misserfolg dieses Kreisprozesses auf personeller Ebene ist mit den Absolventen der Hochschule und deren Rückausse rungen aus der Industrie überprüfbar.

2. FORSCHUNGSEBENE

In der Forschungsebene fliessen mehrere, sich gegenseitig beeinflussende Faktoren zusammen, von denen hier nur drei wesentliche
Elemente aufgegriffen werden sollen:
- Anregungen und Aufträge zu Forschungsvorhaben aus der Industrie oder von industriellen Fachverbänden.
- Spezielle Entwicklungs-Projekte, zu deren Durchführung besonders kleinere Unternehmen keine Kapazität haben.
- Grundlagenforschungen von allgemeinem Interesse.

Gerade diese drei Elemente möglicher Forschungen können sich gegenseitig optimal ergänzen. Dies kann wie folgt ablaufen:

Von der Industrie wird ein fest umrisses Problemfeld der Hochschule zur Lösung angetragen; die Hochschule ermittelt nicht nur die Lösung dieses umrissenen Problemfeldes, sondern bildet gleichzeitig die Grundlage zur Lösung ähnlicher Probleme, die für andere Industriezweige nützlich sein können.

Damit wird nicht nur das reine 'Ergebnis-Bedarfnis' der Industrie befriedigt, auch die Hochschule befindet sich damit auf dem jeweils neuesten technologischen Stand, wenn nicht sogar notwendigerweise auf einer höheren Stufe und kann auf diesem Wege neue Impulse zur weiteren Technologieentwicklung und auch -anwendung geben.

3. BILDUNGSEBENE

Unter dieser Ebene soll nicht nur der Ausbildungs-/Bildungsauftrag der Hochschule den Studenten gegenüber verstanden werden, sondern vor allem Punkte, die unter dem Stichwort 'Weiterbildung' und 'lebenslange Lernen' einen Anspruch der Ingenieure aus der Industrie kennzeichnet.


Weiterhin bedeutet eine solche Bildungsebene, dass in der Industrie auch Bedürfnisse nach bestimmten Lehr- und Lerninhalten und auch Lehrweisen (Methoden) der Hochschule vorhanden sind, die aus den sich wandelnden Tätigkeitsfeldern der Ingenieure in der Industrie resultieren. Eine Forderung nach ständiger Erweiterung der Lehrinhalte an der Hochschule darf daraus jedoch nicht abgeleitet werden, wohl aber eine Hervorhebung bestimmter Prioritäten.

4. KNOW-HOW-EBENE

Den drei beschriebenen Ebenen ist die 4. Ebene, die know-how-Ebene überlagert; das heisst diese Ebenen dürfen sich allein nicht überlassen bleiben, sondern bedürfen einer andauernden Einfluss-
Eine derartige Einflussnahme darf nicht bedeuten, dass eine direktere Steuerung eingreift, sondern dass gewonnene Erfahrungen und Bedürfnisse aus den drei Ebenen aufgenommen, verarbeitet, weiterentwickelt und weitergegeben werden. Dies betrifft vor allem die Bereiche des know-how’s, wie: Grundlagen, Theorien, Analyse, Synthese, Systematik, Aufbereitung zum praktischen Einsatz u.a.

Damit ist vor allem ein Aufgabengebiet der Hochschule, bezw. der Hochschullehrer angesprochen, denn bei ihnen fließen diese Bereiche zusammen. Weiterhin kann gerade an dieser Stelle eine andauernde Wechselwirkung systematisch gefördert und optimal genutzt werden.

5. ZUSAMMENFASSUNG

Mit den hier beschriebenen Kreisprozessen als optimales Zusammenwirken von Hochschule und Industrie wird ein Modell aufgebaut, das die wesentlichen Strukturen zum wechselseitigen Technologietransfer zwischen Hochschule und Industrie beinhaltet und in Teilbereichen zwischen der Industrie und der Hochschule praktisch erprobt ist.1)

Somit kann dieses Modell als eine Empfehlung an die Hochschulen und die Industrie für eine fruchtbare Zusammenarbeit aufgenommen werden.

Nicht nur die Technischen Hochschulen und Universitäten als traditionelle Forschungseinrichtungen sollen mit diesem Modell angesprochen werden, sondern auch Fachhochschulen mit Kurzzeitstudienrängen, bei denen gerade die Forderung nach einem stärkeren Praxisbezug im Vordergrund steht.

1) Laboratorium für Konstruktionslehre (LKL) der Universität - Gesamthochschule - Paderborn; Leitung: Prof. Dr.-Ing. W. Jorden.
INNOVATION MANAGEMENT CONSULTANCY AS MASTER'S THESIS PROJECTS

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ABSTRACTS

At the Department of Industrial Design Engineering of the Delft University of Technology it is possible for a limited number of graduate students to perform a master's thesis project in industry as innovation consultant. The outlines of the theory of industrial innovation, on which these projects are based, are reported and the kinds of problems encountered are discussed. The ways in which projects are acquired and subsequently organized are briefly described too. Conclusions from the experience so far are given.

RESUME

Dans l'article présenté on donne une description d'une certaine classe de thèses d'agrégation à l'école de 'Industrial Design Engineering' de l'Université Polytechnique de Delft, Pays-Bas, dans lesquels l'étudiant agit en fait comme conseil d'innovation pour des compagnies industriels de grandeur moyenne. Les principes de la théorie de l'innovation industrielle sur laquelle ces projects se fondent, sont rapportés, et les genres de problèmes rencontrés sont discutés. On dépeint les méthodes d'acquisition de projets et l'organisation des projets mis en train est décrite. Des conclusions concernant l'expérience jusqu'à a présent sont présentées.

ZUSAMMENFASSUNG

1. INTRODUCTION

Schierbeek reports at this conference on Technology Transfer by graduate students through final training projects in industry (Schierbeek 1982). His emphasis is on product development projects. In this paper I shall report on a particular group of these final training projects (master's thesis projects), viz. projects concerning innovation management.

The need for innovation is high in industry, but many small and medium-sized business have great difficulties in bringing about this severely needed innovation. The aim of the projects discussed is to assist companies in this respect by helping them with a systematic approach to the solving of the problem.

At the Department of Industrial Design Engineering of the Delft University of Technology the outlines of the theory of innovation management are taught in a third year's undergraduate course, supplemented by a series of exercises where cases are treated in order to illustrate and to apply the theory. In the first post-graduate year (the fourth year of the curriculum) the theory is further implemented in an extensive and complicated design project comprising not only a product design but also major features of new business development. In the second post-graduate year (the fifth and final year of the curriculum) the master's thesis project has to be executed. For a limited number of students the possibility exists to perform a master's project on innovation management in industry. These projects can be characterized as consultancy projects.

The philosophy on which the approach is based has been partly mentioned already in the well-known SEFI-report by Tomkins (Tomkins 1979) which laid the foundation for the present conference, and in more detail in a paper by Eekels read before the ICED-conference, at Rome, 1981 (Eekels 1981). The main points will be rehearsed below.

2. THE HIERARCHY OF DESIGN AND DEVELOPMENT PROCESSES

There are several kinds of innovation possible, but here we shall focus on product innovation, i.e. the production and successful marketing of new products. Before a product can be manufactured it has to be designed. This is obvious. The new products if they are successful, are accepted and absorbed by the market and play a role in the societal development process. This is rather obvious too. Now the thesis is framed that between the product design process on the one hand and the societal development process on the other hand two intermediate processes have to be distinguished and to be organized in the company, viz. the new business development process and the product planning process. The latter takes care of the company's development as a whole and it is especially at this level that the company's innovation problems have to be tackled in the first place. The four processes from a hierarchy to be understood in such
a way that the next higher level process encompasses the lower level processes. This is depicted in Fig. 1.

![Hierarchy of design and development processes](image)

**Figure 1. The hierarchy of design and development processes.**

The innermost process is the product design process (numbered 1). It generates the design for a new product, which, after having been manufactured will play its role in the outermost process, the societal development process (numbered 4).

The new product is the basis for a new business, which on its turn has to be designed (or developed as one is used to say; but development in this context is a design process too). After having finished the new product one is not immediately ready for starting the new business. Other aspects than mere product design, such as the manufacturing process, the size of the operation, the marketing strategy, the organization, etc., have to be considered and to be designed as parts of an integrated new business (rectangle numbered 2 in Fig. 1). The phenomenon of the product-life-cycle is a fateful one. It forecasts obsolescence of every product. The reaction of the company should be that it is constantly designing new products to replace existing ones and to develop new businesses around these new products. A fundamental issue at this level is idea finding: what kind of new products are we going to develop, where do the product ideas come from, how do we evaluate them and select the best, how do we set priorities and allocate available budgets, when and on what arguments do we stop projects that look unprospective? These and other questions are subject matter of the product planning process (the rectangle numbered 3 in Fig. 1). The thesis is framed...
that if any one of the processes represented by rectangles 1, 2 and 3 of Fig. 1 is either non-existent, or is not well-managed that then the whole innovative process in the company is stifled. And as in many small and medium sized companies process number 3, the product planning process is lacking indeed one of the main tasks of the consultancy projects under consideration is to get started a more or less formal product planning process.

3. THE STRUCTURE OF THE INDUSTRIAL INNOVATION PROCESS

In order to come at grips with the problems encountered it is useful to depict the structure of the industrial innovation process in the way of Fig. 2.

![Diagram](image)

Figure 2. The structure of the innovative process.

Let us read this model counterclockwise. In order to realize the corporation's objectives (profit, growth, continuity, etc.) the company has to realize new businesses. These have to be preceded by what is called here strict product development, comprising both new product designs and new business development. No new product designs, however, without ideas for new products, and no ideas finally without a strategy. The latter statement seems superfluous. Is it not possible to generate ideas without disposing of a (corporate) strategy? Indeed it is, but the generation of ideas, although it is necessary, is not sufficient. Preferred ideas have to be selected and implemented upon, and practice shows with overwhelming evidence that this is not possible without a governing strategy.

Innovation management has to take care that the process described is brought about, is kept going, is controlled and governed, which means that the necessary decisions are taken. Management means taking decisions. What kind of decisions are needed here?
4. THE CHARACTERISTIC DECISION STRUCTURE OF INNOVATION MANAGEMENT

a. Structure of decisions in general

Decisions have to be taken if alternative courses of action are possible and envisaged. Decision boils down to choosing between various courses of action and enforcing the course of action decided for.

Decisions require two kinds of information: information about the state of affairs under consideration and about the various possible actions, and information of a strategic (and/or ethical) kind, which enables one to evaluate the possible courses of action, and to choose those alternatives that comply in the best way possible with the latter type of normative information.

It is very important to realize that any decision requires both kinds of information and it is startling to observe that in many instances this is not realized at all. One meets situations, especially in smaller companies where abundant factual information is available, but the decision process is inhibited because of lacking strategic information. One meets other situations, e.g. sometimes with government agencies, where all attention is given to the generation of strategic information, but where the decision process is inhibited because of lack of factual information.

b. Divergent and convergent phases in the innovative process

The innovative process as depicted in Fig. 2 actually consists of a sequence of design processes, be it of different abstraction level. Design processes are first of all iterative processes and they consist of a divergent phase and a convergent phase. In the divergent phase alternative solutions for the problem at hand are generated, and in the convergent phase these alternatives are evaluated and the best are selected. The latter is a decision process and the factual information for it consists of the alternative solutions generated. The strategic or normative information consists of decision criteria that should have been fixed at the next higher level of the overall process.

Thus, in the strategy formulation process alternative strategies are generated (divergent process) and with the help of criteria formulated already in the corporate policy the most promising ones with respect to the various aspects of the company's activities (product strategy, market strategy, etc.) are selected (convergent process). They should include criteria for the idea finding process! In the idea finding process product ideas are generated (divergent process) and with the help of the criteria established in the strategies the best ones are selected (convergent process). For any idea accepted to proceed with a clear development instruction should be written, containing the main criteria the design has to comply with. And so on.

As we move in the direction of the arrows in Fig. 2 the processes
become more concrete, and this should be reflected in the criteria.

5. INNOVATION MANAGEMENT CONSULTANCY

Many companies have difficulties with their innovative process. In general they are aware of its necessity but the different way of thinking it requires on the one hand and the absorption of all management attention by short term problems on the other hand often cause it being badly neglected. If the company is wise, it calls in the help of an external consultant.

Roughly speaking the consultant has to bring about the process depicted in Fig. 2 and the best way to do that is to realize that the processes depicted in Fig. 2 have to get started and kept going by suitable organizational measures.

He should take steps that both the factual and strategic information required by each subprocess are generated and that the decision process is kept going.

The consultant will encounter many difficulties of methodological, organizational and psychological kind and he will have to overcome them. Dependent on the maturity of his client he will choose for one of the various models of consultancy, e.g. the process model, the physician patient model, etc. His consulting task will exhibit important educational features. He will act as a change-agent in the most direct sense of the word, and he has a difficult job to perform indeed.

6. INNOVATION MANAGEMENT CONSULTANCY BY STUDENTS: MISSION IMPOSSIBLE?

How do we dare to let inexperienced students act as innovation management consultants where very experienced, highly dedicated and capable managers are unable to do the job themselves? This looks like a mission impossible indeed. Amazingly, however, it proves to work. Why?

In the first place it is not correct to say that those managers are unable to do the job. If they are really unable to do the job, consultancy does not help, unless it causes that management being replaced by a more competent one. Management should at least have the potential to do the job.

In the second place the student's lack of experience is partly set off by his disposing of a theory complete with a briefcase full of methods to tackle the problem.

In the third place the student is accompanied and controlled by a university professor and at least two scientific officers with extended practical experience, which adds a lot both to the capability and the credibility of the student.

In the fourth place the student is often looked at with a certain kind of benevolence which earns him at least the benefit of the
doubt. Companies are aware of the fact that they are contributing to the student's education and that makes them cooperative. Yet the projects prove to be difficult enough.

7. PROBLEMS ENCOUNTERED

In many cases the first difficulty we meet is to find that the company we are going to consult does not correctly see its own problem. Often they feel their problem is one of idea finding, whilst in fact their main problem is the absence of a clear and operational insight what direction the company in the long range should develop into, i.e. what kind of corporate policy should be striven after and what kinds of strategies should be formulated and followed to attain these goals. In general it is of no use to focus on such an error immediately as the conceptual background to admit it is missing. This makes it also risky to define the project in a precise way at its start. What we do is, that we ask the student, who anyhow has to get acquainted with his task environment, to make a description of the company and its functions, and to let this gradually take the form of a strengths/weaknesses analysis of the company. Now from the very beginning we strive after a close cooperation with key-staff employees, also for this initial description and analysis. This phase takes one or two months during which the real problems gradually emerge and become evident both to company management and to the student and his university team although the latter, because of its experience, may have suspected the real problems much earlier. Strategy formulation is a rather abstract process and even if management realizes its necessity then they often show considerable resistance to engage with it. As you may lead a horse to water, but you cannot make him drink, we try to play the game as tactfully as possible, which implies, the whole process anyhow being an iterative process, that we do not hesitate to enter the process of Fig. 2 at any point which looks feasible and then gradually work backward or forward as circumstances allow.

Yet after three or four months the project often runs into a crisis situation. The process to proceed needs decisions, often of a strategy kind, and resistance against taking these kinds of decisions both with top management and/or lower management levels gradually builds up. This is the time to arrange a round table conference where all parties are present, during which the situation is thoroughly discussed, misunderstandings are cleared up, objectives are firmly restated and the sincere intention to cooperate again is renewed. From then on most projects pass off rather straightforwardly.

In many projects emphasis is on idea finding indeed, and this requires much attention both for generating alternative ideas for new products by all kinds of idea generating methods and for formulating and implementing the selection criteria needed for evaluation and choice. The results are often very interesting indeed.
It proves not possible to cover the whole process of Fig. 2 within one master's thesis project of 8 - 12 months. If both strategy formulation and idea finding have to be included we do not come much further than that. If a sound strategy is already available the student can end up with a feasibility study of one or two selected ideas.

8. ACQUISITION AND ORGANIZATION OF THE PROJECTS

We run this type of master's thesis projects for several years now, at present at a rate of 10 - 15 per year. In the near future this may increase to 15 - 30 per year or even more. Projects are acquired in four ways, viz.:

a. Companies apply for consultancy themselves.
b. University staff looks for projects.
c. Students themselves go on acquisition.
d. Various governmental and semi-governmental advisory agencies channel potential projects towards our Department.

The governmental and semi-governmental agencies mentioned under d) are very important in this respect, as they turn out to be instrumental in many instances under b) and c) too. We are happy to say that we enjoy very pleasant and effective relationship with these agencies.

Companies for these projects are mainly searched for in the class of small and medium sized industrial companies that manufacture consumer durables and smaller industrial goods.

The selection of students for these projects is mainly based on the student's own preferences, but also, though to a lesser extent, on their expected capability to successfully perform such a project.

In general the student will be employed by the company on a temporary contract and he will earn a modest salary.

9. CONCLUSIONS FROM THE EXPERIENCE SO FAR

The results up to now after some 25 projects are encouraging. Although various degrees of success have been attained, no definite failure has occurred so far.

The projects show a strong learning effect, both for the students and for the companies in question. It is amazing, but also very satisfying to see how profoundly the attitude of the student in the course of the project is changed towards more mature, more independent and more responsible behaviour. In certain cases you would hardly recognize him or her after the project. (Several girl-students performed excellent projects indeed.) But not only the student undergoes a change, also the company can undergo a definite change in
attitude concerning its strategic, future-directed behaviour. Finally, the system of projects as a whole forms a strong learning process for the scientific staff of the university department concerned.

Yet we feel that the projects can still be improved. Part of the improvement should come from better preparing students for their consulting task. They should be taught more about the various ways of consulting, and they also should know more how to deal with organization psychological problems. We are underway to insert introductions to these items into our courses.

As to the main direction of our innovation management consultancy projects as master's theses, however, we feel that we are pretty well underway.

10. ACKNOWLEDGEMENT

The success of the projects mentioned is to a great extent due to the efforts of many colleagues and scientific officers of the Delft University of Technology. Especial mention in this respect deserve three senior scientific officers of my group at the Department of Industrial Design Engineering, viz., Ir. L.P. Bienfait, Ir. H.P.M. Diepstraten and Ir. W. Nijhuis.

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ABSTRACT

Innovation has to be managed very systematically because the costs and the risks of innovation are high. Besides the use of existing management methods and techniques in the various phases of the development process itself, the entrepreneur has to have more insight in the conditions for innovations (the establishment of an innovative climate in the organization and the application of creativity techniques). Furthermore he has to take into account the organizational and financial aspects of innovation. Finally he needs understanding of the adoption process for the marketing planning and the smooth progress of the diffusion of innovations.

RESUME

Les frais et les risques des innovations étant élevés il est nécessaire que celles-ci soient dirigées d'une manière très systématique. Il devra en être de même pendant les phases du développement proprement dit, comme pour celles qui le précèdent et le suivront. L'entrepreneur doit créer un climat innovatif dans l'organisation et y augmenter le pouvoir créatif. Ensuite l'entrepreneur doit être attentif aux aspects d'ordre financier comme à ceux se rapportant à l'organisation elle-même. Enfin il devra avoir à son actif certaines notions du procédé d'adoption enfin d'assurer un bon fonctionnement au plan de marketing et à la diffusion des innovations.

ZUSAMMENFASSUNG

1. INTRODUCTION

We know that innovation is a necessity for organizations to adapt to changes in their environment. We do not realize enough, that these changes moved quicker and became more complex in recent years, because of the interactions between them and the organization. In the same time innovations became more expensive and risky. These reasons ask for a (more) systematic approach of innovation, e.g. for management of innovation. Management of innovation is broader than carefully managing the innovation process itself by the use of management methods and techniques, reducing the change of failure and reducting the costs of innovation.

It includes also establishing a climate of change and innovation. This is necessary because people as you and me offer resistance against change, especially when we don't exactly know the reason(s) for change. The results of this mostly not noticable resistance of people in organizations is: higher costs of innovation, delay in the implementation of decisions, and even failure. The innovative capacity of the organization can be broadened by organization development approaches and by the use of creativity techniques. The management of innovation is primarily a task of the entrepreneur or the manager. He needs therefore an accessibility for changes and a flexibility and creativity to translate changes in the environment into new possibilities (products/markets). This innovative attitude can't be learned by attending lectures or reading books. The only way is an intensive training during which the manager/entrepreneur develops this attitude himself, with the help of professional trainers.

2. THE CLIMATE OF INNOVATION

The development of a positive climate for change and innovation is a prerequisite for the realisation of innovations. This is therefore one of the first tasks of the manager. In fact it means the development of an attitude of the employees that is open for changes and at the same time market-oriented. The possibility and motivation of the employees to develop such an attitude depends among other things of the possibility for participation. Other important aspects are for example the salary structure, safety-aspects, job enrichment. In other words, aspects which are important for the quality of (working) life. To realise that people have no fear and therefore no resistance for changes, it is in the first place necessary to explain the reason(s) and/or the necessity for changes. Furthermore the employees have to learn to look at changes not only as possible threats, but also as a broadening of the possibilities, or even as a necessity for survival of the company. For example: the Dutch have in general an enormous resistance against change from one job to another. This means not only an inflexibility within organizations but also for the total labour-market.
To be accessible for changes is not only something for the top of the company but it has to be an attitude of the people on all levels in the organization. This is a condition for innovation of organizations and their activities in the future.

To create a climate of change and innovation there are various techniques and approaches, known under the name "organizations development". In theory two different approaches can be distinguished:
- The process and human directed approach
- The more technique-structural approach, directed to "job and organization design", job-enrichment, socio-technical systems etc. These approaches improve the quality of work and its effectiveness. A more direct motivation of the employees is stimulated by the installment of consultation institutions or structures by which the participation of employees is broadened. These structures and institutions, workers' councils can only be effective if the entrepreneur gives it enough importance and sufficient support.

3. CREATIVITY

The Innovation-process appeals to the creativity of the organization and the employees. In the first place for the invention of new product/market-combinations (the generation of new ideas). In the second place for the generation of alternative solutions for the problems that arise in the various phases of the innovation-process. It is said already that innovation is a time-consuming and expensive activity. During the application of creativity-techniques time-savings can be obtained as well as improvement of the effectiveness of the innovation process.

J.P. Guilford made a distinction between convergent and divergent thinking. With convergent thinking all information we hear, see and feel, is screened by a censor. This censor is programmed by our environment, education and experience. For successful innovation we have to break through this convergent thinking-pattern. This is possible by the training and use of some (divergent) creativity techniques. These divergent thinking-techniques are directed to the creation of as much as possible new ideas by the use of analytical techniques (morphologic analysis, forced relationships, attribute listing), association techniques (brainstorming) and analogic techniques (synectics).

4. THE DEVELOPMENT OF AN INNOVATION STRATEGY

Even on this moment we are not ready for the innovation process itself. In the foregoing we discussed the establishment of a climate of change, by the entrepreneur as a prerequisite for innovation, and the increase of the innovative capacity of the organization by the use of creativity techniques. First of all it is necessary to make an innovation plan, because it is not very effective to innovate "in the blind". After the generation of new ideas we have to select these ideas with the help of some criteria. A stra-
tegic plan contains such criteria. The process of strategic planning consists of the following activities:

a) analysis of the environment and an analysis of the company;
b) the formulation of goals and the development of a strategy;
c) the development of a plan of operations.

The analysis of the environment can be structured by checklists in which questions about developments and trends in the various social fields as demography, economy, law, politics, technology and culture. We can make a distinction between world-wide developments, developments within the E.E.C. and finally within the Netherlands e.g.

For the analysis of the company there are a lot of techniques for the financial analysis, the product-market analysis, competition analysis. It is a process that is difficult to structure but leans heavily on the feeling and intuition of the entrepreneur.

After the strategy is formulated, the entrepreneur has to develop an operational plan.

5. THE PRODUCT-DEVELOPMENT PROCESS

The strategic plan of the company leads to identification of the innovation-areas, so, an innovation-plan can be set up. This plan contains the criteria for innovation with respect to market-, financial and product-technical aspects. Because the risks and costs of innovation are high, the process of product-development has to be guarded. Therefore the process is divided in some phases, and after each phase there is a decision-moment: go or not-go (to the next phase). These phases are: a) idea-generation; b) selection of ideas; c) business analysis; d) product development; e) test marketing; f) commercialization.

For these phases are usually broadly discussed in the existing literature about product-innovation and in the marketing literature we just give this enumeration.

In the last part of this paper we like to discuss successively organizational aspects of innovation, financial aspects of innovation, and the diffusion and adoption of innovations.

6. ORGANIZATIONAL ASPECTS

Even if we have established an innovative climate with the use of the various organization development techniques, and if we have trained our staff in the use of creativity techniques, and if we have planned the innovation-process systematically with the use of modern existing management techniques, even then product-development can be characterized by frustration and stagnation. The reasons for this have to be searched in the internal communication of the company and in not adequate organization structures. Simply said the "normal" organization is so occupied with their own day-to-day work that there is no attention enough for the new project(s). Therefore special functions and/or organizational structures have to be crea-
ted, which have a specific responsibility for the innovation project:
- productmanager, with specific responsibilities for product development, but his main function lies within his own product group.
- new productmanager or productplanner, with no other tasks than development of (a) new product(s).
- productdevelopmentcommittee: review and selection of new product proposals, but this interdisciplinair team stays often to far from the development process itself.
- department for product development. This is possible in large companies. Considerable responsibilities and direct entrance to the top-management. Disadvantage: the integration of the new developed product into the product- and marketing organization.
- new product venture-teams.
  A team composed of experts from the various departments of the company. The membership varies within the various phases of the development process. The team is disbanded as the product has been launched succesfullly and has been turned over to the existing marketing organization.

7. FINANCIAL ASPECTS

Innovation costs a lot of time and money and also here counts "in order to make money you have to spend money". To get a clear picture of the financial problem of an innovation project the entrepreneur first of all has to analyse the development of the costs during the development process. Figure 1 gives an impression of the cumulative costs (in time and money) of an average development process. Of course it is necessary to refine this picture for a specific product. This offers an estimation of the total costs of the development process, and of the various phases.
Furthermore it is necessary to know the product-life cycle including estimations of the turnover and the profits of the new product. An example of a product-life cycle you can find in figure 2. The two analyses give an estimate of the financial needs for the total project and the liquidityproblems during the project-life. On the basis of these analyses the entrepreneur can decide to attract the needed amount and type of financial resources.

8. DIFFUSION AND ADOPTION OF INNOVATION

The introduction of a new product can be confronted by resistance, because it means "change". This resistance can lead to delay of the introduction, and that is very expensive. Because of this the diffusion-process, that is the spread of innovations from the source to the ultimate users, has to progress smoothly. Therefore we have to study the adoption process, that is the mental process of an individual from the moment he or she hears of the new product until the moment the product is accepted. Important aspects of the
The factors that determine the time of the adoption process are the complexity of the change caused by the innovation; the costs of the innovation, the rate of return; the visibility (on short term) of the results. The way innovations are accepted follows a recurrent pattern: the adoption process. The phases of the adoption process are a) awareness; b) interest; c) evaluation; d) trial and e) adoption. The entrepreneur has to think carefully about new-product acceptance. Not everybody completes the adoption process in the same way or at equally fast: Some individuals (2½% of the potential consumers of a new product) are the innovators and 13½% are early adopters. Then an average of 16% is always the last group to accept new products (the laggards). Then remains a big group of 68%, that can be divided in an early majority (34%) and a late majority (34%). An understanding of these various categories and the various phases of the adoption process, can help with the planning of the marketing of new products, and in general it facilitates the diffusion of innovation in society.
Figure 2. Product Life Cycle

LITERATURE

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ABSTRACT

In the present curricula of Engineering education there is no course which transmits the knowledge about the complete area of engineering such as Mechanical, Electrical or Civil Engineering, showing the fundamental relations and topology of the field.

Theory of Technical (machine) Systems can be used for such a purpose because it answers all these questions. It is also able to explain the positions and functions of other elements (subjects) in the curriculum. The new discipline is supporting the transfer of experience and knowledge between different families of products and consequently effects the innovative approach of an engineer. The paper describes the goals and the structure of the theory and shows the possibilities of application.

RESUME

Les curricula sur l'Education de la Mécanique élaborés jusqu'aujourd'hui, ne contiennent aucun cours qui transmette d'une façon complète les connaissances du domaine de la Mécanique, de l'Electricité et celle de Bâtiments, en montrant les relations fondamentales et la topographie de ce domaine.

On peut arriver à ce but à l'aide de la Théorie des Systèmes techniques, parce que celle-ci donne des réponses à toutes ces questions. Elle peut aussi expliquer les positions et fonctions des autres sujets de ce curriculum. Cette nouvelle discipline supporte la transmission des expériences et connaissances entre les différentes familles de produits et, par conséquent, inspire à l'ingénieur un accès innovatif.

La communication explique les buts et la structure de la théorie et montre les possibilités de son application.

ZUSAMMENFASSUNG

Die heutigen Lehrpläne aller Schultypen für die Ingenieursausbildung enthalten kaum Lehrveranstaltungen, die das Gesamtlehrgebiet (z.B.

1. DIE ZIELE UND LEHRPLÄNE DER INGENIEURAUSBILDUNG


Damit sind die Lehrziele der Ausbildung von der Fachseite massgebend beeinflusst und zugleich die Elemente, die im Lehrplan Eingang finden. Neben den lehrstoffimmanenten logischen Zusammenhängen sind auch gnoseologische und didaktische Aspekte zu berücksichtigen.

In jedem Fall muss der Lehrplan einer Ingenieurschule ein System bilden, dessen Elemente sich dem Gesamtziel der Ausbildung (d.h. besonders die Aenderung der Qualifikation des Schülers) anpassen müssen. Die meisten Schulen bleiben dieser Einheit sehr viel schuldig und zwar auf mehreren hierarchischen Ebenen, besonders jedoch in der Frage nach dem Gesamtziel. Damit sind auch die einzelnen Elemente (Lehrveranstaltungen) in Frage gestellt. Vom didaktischen Standpunkt verletzt man damit mehrere pädagogische Prinzipien wie z.B. die der Kongruität, Diskrimination und Einsichtigkeit. Auch das Prinzip der Wiederholung kommt dabei zu kurz.

Die allgemeine Diagnose kann so lauten, dass es in den Lehrplänen
der heutigen Ingenieurschule an Lehrveranstaltung(en) mangelt, die besonders
- eine Gesamtorientierung im Fachgebiet (z.B. Maschinenbau) leistet.
- eine mindestens grobe Struktur des Fachgebietes mit seinen Bestandteilen und Relationen darstellt.
- grundlegende Gesetzmäßigkeiten des Fachgebietes zeigt.
- wichtigste Problemkreise des Fachgebietes ableitet und damit auch bisherige Entwicklungen und künftige Forschung andeutet.
- die Rolle und Position der am Lehrplan beteiligten Lehrveranstaltungen verdeutlicht.

2. THEORIE DER MASCHINE

Wenn wir uns mit weiteren Überlegungen auf den Boden des Maschinenbaus begeben klingt vorerst plausibel, dass für dieses Gebiet die Maschine als Repräsentant angenommen werden kann und die "Theorie der Maschine" als Wissensgebiet die diskutierte Lücke schliessen könnte. Ähnlich dann ein Bauwerk oder ein Elektrosystem, die die Zweige Bauwesen oder Elektrotechnik repräsentieren können.


Mit dem Ziel, die Meinung einiger Ingenieure, Wissenschaftler und Dokumentare zu erfahren, denen diese Auffassung nicht bekannt ist, habe ich ungefähr hundert Fachleute gefragt, was sie unter Theorie der Maschine verstehen und wie sie die Bedeutung solcher Theorien schätzen. Ohne behaupten zu wollen, dass damit ein Ergebnis einer wissenschaftlichen Erhebung präsentiert ist, wurde die Antwort fast eindeutig: es geht um ein allgemeines, alle Maschinen (ohne Definition!) betreffendes Kenntnisystem, das alle Einzelkenntnisse verbindet, und ordnet; also die Meinung der Theorie als logisch systematische Zusammenfassung und Verallgemeinerung von Erkenntnissen über einen Bereich der Wirklichkeit (hier der Maschine), welche wesentliche Zusammenhänge in be-
gründender und erklärender Weise wiederspiegelt. Über die Bedeutung und die Nützlichkeit eines solchen Systems wurde kein Zweifel ausgeprochen, sondern eher Unsicherheit, ob so etwas existiert und eigentliches Staunen, dass von der Schule kein entsprechendes Wissen vorhanden ist.

3. ÜBERSICHT NEUER BESTREBUNGEN IN DER "MASCHINENTHEORIE"

Die Bestandesaufnahme und Analyse der allgemeinen Maschinentheorie wäre nicht vollständig, solange nicht einige Versuche erwähnt würden, die in der Richtung der allgemeinen und ganzheitlichen Betrachtungsweise der "Maschine" gehen. Es sind dabei drei Aspekte charakteristisch - einmal die Anlehning an die Kybernetik und besonders an die Systemtheorie, zweitens die Versuche, neue Begriffe für die "abstrakte Maschine" zu schaffen und drittens die Verbindung mit dem Konstruieren.


4. THEORIE DER MASCHINENSYSTEME


Die Maschinensysteme sind weder nur Mechanismen noch lauter Automaten. Folglich kann eine Mechanismenlehre oder Automatentheorie keine allgemeine Theorie bilden wie es bei Artobolevskij der Fall war. Dies sind nur Teiltheorien, um Bewegungen der Steuerungen der MS zu erreichen, d.h. nur einige Eigenschaften unter den vielen. Für die Theorie der MS soll gelten:

a) Ziel der Theorie
Erkenntnis der allgemeinen Gesetzmäßigkeiten im Objektbereich der Maschinensysteme
b) Aufgabe der Theorie

Die Beschreibung und Gesetzmäßigkeiten in
- Aufbau des Systems und dem Zweck
- Eigenschaften und ihrer Verwirklichung
- Entstehungsprozess und seinen Faktoren
- Aufeinanderfolge in der Geschichte und
- Arten und Familien

c) Einzelne Zweige (Struktur)

Die genannten Aufgaben entsprechen einzelnen Zweigen
- Zweck, Beziehung zur Umwelt (MS-Oekologie)
- Aufbautheorie (Anatomie): welche den Aufbau des MS erforscht mit
dem Ziel Strukturmodelle der MS zu ermitteln
- Prozesstheorie: die Erforschung des Geschehens bei den künstli-
chen Transformationen, die mit Zweck und Wirkweise der MS eng
verbunden sind.
- Eigenschaftstheorie allgemein: erforscht die Eigenschaften und
Konstruktionsmerkmale der MS und ihre Beziehungen.
Bewertungstheorie (Qualitätstheorie) kann als Teilgebiet der
Eigenschaftstheorie betrachtet werden.
- Entstehungstheorie (Genetik des MS): untersucht alle Stadien des
MS von der Planung bis zur Liquidation. Als Teilgebiete können
z.B. Konstruktionstheorie und Herstellungstheorie genannt werden.
- Entwicklungstheorie: erforscht die Aufeinanderfolge der MS-Gen-
erationen in der Geschichte.
- Systematik: untersucht die Arten der MS (Artlehre) von verschie-
denen Gesichtspunkten und die Verwandtschaft der MS-Arten.

Von dieser Aufzählung der Zweige ist die Breite der gestellten wis-
senschaftlichen Fragen ersichtlich.

d) Arten der Theorie

Je nach dem Gültigkeitsbereich unterscheidet man
- allgemeine Theorie, die für alle MS gültig ist.
- spezielle Theorien, die für einzelne Arten von MS konkretisiert
  sind. z.B. Strömungsmaschinen, Verbrennungsmotoren, Mechanismen,
  Maschinenelemente.

5. DIE BEZIEHUNG DER ALLGEMEINEN THEORIE DES MS ZU ANDEREN DISZIPLINEN

Die allgemeine Theorie der MS baut auf mehreren Wissenschaften auf;
ihre Zahl wächst stetig mit der Breite des Einsatzes der MS, den stei-
genden Anforderungen bezüglich technischer und wirtschaftlicher Para-
meter und Bestreben nach Effizienz der Prozesse. Die Zeiten sind vor-
über, wo die Physik und besonders die Mechanik die einzigen Quellen
der Fachinformation waren. Sie gelten zwar noch immer als wichtigste
Säulen des Kenntnisreservoirs, aber eine ganze Reihe neuer Disziplinen
ist dazugekommen, wie z.B. Kybernetik, Biomechanik, Wirtschaftswissen-
schaften, Elektronik, Ergonomie oder technische Aesthetik.

Die allgemeine Theorie bildet für den Ingenieur einen Rahmen und ein Ordnungssystem für technische Disziplinen, die im Zusammenhang mit Konstruieren, Fertigen, Prüfen, Verkaufen, Lagern, Transportieren, Betreiben und Vernichten der MS angewendet werden. Ich versuche mit einigen Beispielen diese Zuordnung zu verdeutlichen. So z. B.

- Festigkeitslehre ist in dieser Auffassung der Eigenschaftstheorie zugehörig, weil sie Beziehungen zwischen Festigkeit (Eigenschaft) und anderen geometrischen und werkstofflichen Eigenschaften hat.
  Aehnlich: Ergonomie, Dynamik, Kynematik.

- Strömungslehre erfasst Prozesse der Strömung; ist also eine spezielle Prozesstheorie.
  Aehnlich: Steuerungs- und Regelungstechnik, Wärmelehre, chemische Technologie.

- Mechanismenlehre ist eine spezielle MS-Theorie, die Mechanismen (= MS die Bewegungen als Aufgabe haben) behandelt und somit alle Zweige der Theorie in Anspruch nimmt. Ihr Teil Mechanismensynthese ist Teilgebiet der Entstehungstheorie (wissenschaftl. Frage ist: wie erreiche ich eine erwünschte Bewegung?).
  Aehnlich: Maschinenelemente, Strömungsmaschinen, Turbomaschinen, Textilmaschinen.

6. DIE BEDEUTUNG UND MOGLICHKEITEN DER ALLGEMEINEN THEORIE DER MS


Diese Vorteile hat sich die allgemeine Konstruktionswissenschaft zu Nutze gemacht. Die historische Skizze zitierte einige Namen.

Ein besonderer Effekt kann durch die Theorie in der Ausbildung erzielt werden. Einmal in der allgemeinen Bildung im Fach Technik, wo es um eine ganzheitliche Orientierung geht, dann aber speziell in der Ingenieurausbildung, wo eine integrierende Theorie für einzelne Fachgebiete fehlt.

7. POSITION DER THEORIE IN LEHRPLÄNEN UND IHRE DIDAKTIK

Die Theorie kann im gesamten Lehrplan zwei Funktionen übernehmen:
- Einführung in das Studium mit besonderen Aufgaben: Verständnis der Problematik und zu erreichende Uebersicht, Zweck einzelner Lehrfächer zu erklären.
- Rekapitulation am Ende des Studiums: den vermittelten Lehrstoff in Zusammenhang bringen.

Die Lehre der Theorie müsste sich der schwierigen Aufgabe anpassen und besonders im Stoffaufbau und der Präsentationsform muss eine geeignete didaktische Konzeption gesucht werden. Die Art und Weise des Unterrichts, besonders in der Einführung, kann das Verhältnis der Studenten zum Fachgebiet sehr positiv beeinflussen und folglich ihre Motivation.

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ABSTRACT

Created at the beginning of the fifties by L.D. Miles in the USA, the Value Analysis (VA) Method is now considered by the most important industrial firms as a key-instrument for reducing the costs of the products, for developing innovation and for a strategical management.

The originality of the VA-Methode consists in the mixing of very efficient approaches: the functional analysis (to consider priori­tary the functions of the product), the cost analysis, the creativity methods and the use of VA working groups.

The use of VA-Method is now well developed in various countries (USA, Japan, West-Germany, UK, Italy, France, ...).

As initial General Secretary of the french AFAV (Association Française pour l'Analyse de la Valeur) and Chairman of its Working Commission on Formation (Education and Training) in VA, the author examines:
- The relations between VA and Innovation.
- The difficulties for introducing the VA-Method into the practices of the firms and of the engineers.
- The possibilities to train young engineering students, within the engineering schools, for the use of the VA-Method.

RESUME

Créée au début des années 50 par L.D. Miles aux États-Unis, l'Analyse de la Valeur (AV) est considérée par les plus importantes sociétés industrielles comme un outil indispensable pour réduire les coûts des produits, pour promouvoir l'innovation et pour le management stratégique.

L'originalité de la méthode AV réside dans la mobilisation de différentes approches: l'analyse des fonctions des produits, l'analyse des coûts, les techniques de créativité et le recours au Groupe de Travaill AV.

L'usage de l'Analyse de la Valeur est aujourd'hui bien développé dans de nombreux pays (USA, Japon, RFA, Grande-Bretagne, Italie, France, ...).

En tant que membre de l'Association Française pour l'Analyse de
la Valeur (AFAV), l'auteur examine:
- Les relations entre Analyse de la Valeur et Innovation.
- Les difficultés de prise en compte de la méthode AV dans les pratiques des entreprises et des ingénieurs.
- Les possibilités de former les élèves futurs ingénieurs à l'emploi de l'Analyse de la Valeur.

1. L'ANALYSE DE LA VALEUR, MÉTHODE D'INNOVATION

1.1. Quelques points d'histoire

L'Analyse de la Valeur (Value Analysis est née aux USA dans les années de l'immédiat après guerre, au sein d'une grande société américaine, la General Electric.

Son inventeur, L.D. Miles, cherchait alors à réduire le coût des approvisionnements de la société et cela de manière substantielle.

La méthode passe très vite en usage dans le secteur de la Défense, aux USA, et est même défendue par M. MacNamara lui-même.

L'Analyse de la Valeur devient une pratique courante au sein des entreprises américains qui, grâce à elle, améliorent leur compétitivité.


La méthode se développe et donne naissance par exemple au Design to Cost (Conception pour un coût optimum), au Design to a Life Cycle Cost (Coût global), à la naissance enfin du Cahier des Charges Fonctionnelles (CdCF).


1.2. Quelques définitions

L'Analyse de la Valeur est une méthode de conception (ou de re-conception) de produits ou de services qui a pour objectif d'améliorer la réponse apportée par ces produits ou services aux besoins des utilisateurs, tant en ce qui concerne les qualités fonctionnelles de ces produits que leur coût.

L'Analyse de la Valeur est une méthode qui s'appuie:

a) Sur une Analyse des Fonctions des produits.
b) Sur une Analyse permanente des Coûts de ces produits.
c) Sur un travail en groupe qui associe les différents partenaires concernés par les produits en question.
d) Sur un effort constant de créativité.

L'Analyse de la Valeur s'applique, soit à des produits existants dont elle cherche essentiellement à réduire le coût (10, 20, 30%, ...):
Value Analysis; soit à des produits nouveaux à créer: Value Engineering.

Un investissement de 1 en Analyse de la Valeur donne généralement lieu à un gain de 20 sur les produits concernés.

La méthode d'Analyse de la Valeur est enfin au cœur du processus d'Innovation est un puissant outil de stratégie industrielle pour l'entreprise.

2. L'ANALYSE DE LA VALEUR ET LA FORMATION DES INGÉNIEURS

2.1. Constat

L'Analyse de la Valeur qui commence à être très largement utilisée par les milieux industriels (avion AIRBUS, lanceur spatial ARIANE par exemple) est quasiment ignorée des milieux éducatifs et notamment des formateurs d'ingénieurs.

À la limite, une méthode telle que l'Analyse de la Valeur, ne peut-être que systématiquement repoussée par un corps enseignant qui privilégie exclusivement la transmission des connaissances.

D'une manière générale, les méthodes de conception de produits ne sont pas aux programmes des Écoles ou Universités formant les ingénieurs.

Approcher la conception des produits par le biais des FONCTIONS de ces produits n'est pas une démarche courante.

Le raisonnement sur les coûts des produits est totalement absent de l'Université.

Enfin le travail en groupe pluri-disciplinaire où s'échangent des informations sur les techniques, les coûts, les opportunités de marché, etc., ..., n'est pas non plus une pratique courante des milieux éducatifs.

2.2. Tendances récentes

Sans parler des expériences japonaises qui montrent que des dizaines de milliers d'ingénieurs, techniciens et commerciaux des grandes sociétés japonaises sont formés à l'Analyse de la Valeur, on peut citer l'existence en RFA d'une norme DIN sur la formation à l'Analyse de la Valeur (mais les Universités techniques font-elles réellement quelque chose dans ce domaine?) ou encore les systèmes de qualification d'experts en AV aux USA. Citons également les enseignements dispensés au Canada.

En France, l'AFAV s'est donnée comme objectif de trouver des solutions à ce problème de formation à l'Analyse de la Valeur.

D'ores et déjà, une vingtaine d'Écoles d'Ingénieurs ont inscrit à leur programme des initiatives ou des formations à l'Analyse de la Valeur. C'est encore trop peu. Un vaste effort va être prochainement entrepris pour sensibiliser les Directeurs des Grandes Écoles Françaises d'Ingénieurs à l'Analyse de la Valeur.
3. ANALYSE DE LA VALEUR ET FORMATION DES INGÉNIEURS À L’INNOVATION

3.1. Apprentissage

Peut-on réellement disserter sur la formation des ingénieurs à l'Innovation, sans prendre d'initiatives visant à faciliter l'apprentissage de méthodes en usage dans l'Industrie et dont l'efficacité est aujourd'hui prouvée.

L'introduction des méthodes de Conception de produits dans les programmes de formation des Ingénieurs doit elle même être résolument innovatrice.

Des pratiques de conception de produits, recourant à des méthodes telles que l'Analyse de la Valeur doivent être introduites dès les premiers cycles de la Formation. Elles doivent systématiquement être utilisées aussi souvent que possible tout au long de la formation des Ingénieurs.

L'Analyse de la Valeur peut d'ailleurs faciliter la structuration du programme d'apprentissage et mettre en relief les priorités parmi les composantes de ce programme.

3.2. Recommandations

Au-delà des expériences ponctuelles, il est souhaitable de procéder à une étude approfondie et internationale de ce qui est actuellement fait pour initier ou former les futurs ingénieurs à des méthodes telles que l'Analyse de la Valeur.

La SEFI peut jouer un rôle dans ce domaine, en s'appuyant sur les diverses organisations nationales qui, depuis plusieurs années, tentent de promouvoir cette méthode d'innovation.

Une telle étude nécessite de sortir du champ trop fermé des institutions universitaires (quasiment ignorantes en la matière) et doit se développer au sein des milieux industriels eux-mêmes.

4. APPEL

Pour conclure, l'Auteur, membre fondateur de l'Association Française pour l'Analyse de la Valeur, ne peut que souhaiter que se développe, au niveau européen, une telle réflexion sur la formation des Ingénieurs aux méthodes de conception et parmi elles, l'Analyse de la Valeur.

Il invite les personnes intéressées à prendre contact avec lui.

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5. REFERENCES

STÄNDIGE ANPASSUNG DES INGENIEURSAUSBILDUNG AN INNOVATIONSPROZESSE UND DEN FORTSCHRITT IN WISSENSCHAFT UND TECHNIK

Martin Mittag
Maria Rain, Sipperhof
Austria

ZUSAMMENFASSUNG


In einem ausführlichen Arbeitspapier (Referat) kann eine detaillierte Darstellung des gegenwärtigen Standes der Arbeiten des IACEB gegeben werden.
ABSTRACTS

Overabundance of information encourages the mere learning of facts. Dealing with models leads to the idea, that the functioning of a machine is more important than its service to mankind. This causes tension between producers, users, and the environment.

A contrasting approach is presented here in a new course of study. While technical topics make up part of the course, there is opportunity to work on projects. These serve to motivate the more formalized courses, to instill a sense of responsibility, and to introduce new techniques.

Projects completed and literature are listed.

RESUME

Le flot d'informations ne stimule que l'apprentissage de faits. L'étude de modèles fait penser que le fonctionnement de la machine est plus important que son utilisation pour les hommes. Ceci crée des tensions entre les producteurs et les utilisateurs et l'environnement concerné.

Par contraste avec cela on présente un programme qui, à côté d'éléments de disciplines techniques, laisse place à des projets. Ceux-là servant aussi bien à stimuler la motivation pour des cours structurés qu'à former le sens de la responsabilité des techniciens et à apprendre d'autres manières de travailler.

On cite des projets réalisés jusqu'ici et on donne des indications bibliographiques.

ZUSAMMENFASSUNG


Es werden bisher durchgeführte Projekte benannt und Literaturangaben gemacht.
1. EINLEITUNG

Technischer Fortschritt und kritisches Fragen nach den späteren Folgen der in Rahman dieses Fortschritts gefertigten Produkte sind zwei Dinge von erheblichem Gegensatz; diese Erfahrung machten alle, die im vergangenen Jahrzehnt technische Ausbildung in ihren Grund- und Folgen in Erscheinung stellten.

Wer daher Änderungen in der Einstellung wie in der Ausbildung anstrebt, muss zuerst zu ergründen versuchen, welche Bedingungen zu diesem Widerspruch führten und noch führen.

Er muss weiterhin begründen, warum er Änderungen für notwendig hält und muss dies so glaubhaft machen, dass dabei auf Dauer eine breitere Wirkung erzielt wird, als sie als Folge der bisherigen An- setze sichtbar wurde, so u.a. in Teilen der Ausbildung technischer Lehrer, bei Architekten und Bauingenieuren.

Er muss drittens Vorschläge machen, wie sich und mit welchen Hilfsmitteln Änderungen der Haltung und Einstellung im technischen Unterricht vermitteln lassen.

Diesen drei Aufgaben widmet sich das Referat.

2. EINE ANALYSE DER MERKMALE TECHNISCHER AUSBILDUNG

a. Die mangelnde Komplexität


Nun werden aber an den Anfang der Grundlagenfächer niemals reale technische Dinge, sondern immer nur deren Modelle gestellt, deren Abstraktion gerade so weit getrieben wird, dass sie in sich wider- spruchsfrei sind.

Damit wird die Komplexität eines Produktes, das ja niemals nur Selbstzweck, sondern immer ein dem Menschen dienliches Ding sein soll, aus dem Lernprozess ausgeblendet: Eine Fülle von Berechnungs- verfahren, die sich durch immer höhere Genauigkeit und sorgfältigere Beschreibung der Einzelfunktionen des Gerätes hervortun, verstellen dabei die Sicht für die Umgebung, in die dieses Produkt eingebracht werden soll, in die es aber auch eingepasst werden muss.

Da jedoch diese Umgebung an keiner Stelle Gegenstand der Aus- bildung gewesen ist, darf letzteres sehr bezweifelt werden. Und da nach den Regeln der Ausbildung kein prinzipieller Unterschied zwi- schen der Behandlung einer Hüttenstromversorgung und einem öffent- lichen Kraftwerk, zwischen einem Lagerstapelfahrzeug und einem Müll- transporter bestehen, gelten die gleichen Zielprozesse für werk- interne wie für externe Produkte, werden die Komponenten Mensch, Umwelt, Betroffene und Zukunft im Kalkül immer nur den letzten
Stellenwert oder - im Grundstudium - gar keinen haben.

b. Die Angst vor gemeinschaftlicher Arbeit


Andererseits fordert eine sich unaufhaltsam steigernde Welle der Aenderung technischer Ergebnisse, wie sie mit den verschiedenen Stufen der Datenverarbeitung und Kommunikationsmittel auch in den kleinsten Betrieb eingedrungen ist, eine vom Einzelnen nicht mehr allein vollziehbare Anpassung und Umstellung; die Flut der Informationen und die wachsende Konkurrenz auch durch bisher kaum entwickelte Ländern wird einen effektiven Einsatz des technischen know hows der Industrieländer nur bei selbstverständlich gewordener Zusammenarbeit ermöglichen.

Warum aber sollte Zusammenarbeit dann nicht geübt werden? Was berechtigt zu der Annahme, dass es leichter sei, eine gemeinsame Zieelperspektive durch lauter Individualisten aufbauen zu lassen, statt durch solche, die auch bei kleinen Aufgaben schon miteinander tätig gewesen sind?

c. Die Notwendigkeit exemplarischer auswahl

Der an jeder neuen Technischen Hochschule oder Gesamthochschule bei der Aufstellung von Ausbildungs- und Prüfungsordnungen aufbrechende Streit um die Studienanteile der einzelnen Fächer und Arbeitsbereiche ist ein eindeutiges Signal für die Tatsache, dass niemand mehr wirklich glaubt, die Fülle des nach wie vor wachsenden Grundlagenwissens, insbesondere aber des exponentiell steigenden Anwendungswissens in dem ihm zugestandenen Rahmen unterbringen zu können.


Die Kunst einer auf die Zukunft gerichteten Ausbildung wird daher neben der Formulierung der notwendigen Zuwächse in der gleichzeitigen Angabe des Wegzulassenden liegen, wird den Anspruch auf Unabhängiges verringern müssen, um wirklich Wichtiges herauszustellen. Einige vorgängig gewählte Exempla, gut gelernt und
mehrfach geübt, haben mehr Chancen auf spätere Verwendung als die
überwiegend auf das Bestehen der Examen ausgerichtete Lernfülle.

3. UMSETZEN DER KRITIK IN AUSBILDUNGSELEMENTE

a. Aus der Sicht der Lernenden

Aus den drei Teilen des vorigen Kapitels kann auf eine Ausbildung
geschlossen werden, die die folgenden Elemente miteinander vereini-
gen muss:
- Parallel zum Erwerb systematisch aufbauender Kenntnisse in den
Grundlagen von Mathematik, Physik, Werkstoffenwissenschaft, Kon-
struktion und Grundschaltungen wird ein reales technisches System
mit seinen technischen Details, seinen Herstellungsverfahren, seinen
ökonomischen und seinen ökologischen Bedingungen vorgestellt und
als Ganzes begriffen; damit wird es zum Ausgangspunkt von Einzel-
studien, die den Erwerb bestimmter technischer wie nichttechnischer
Kenntnisse in gleicher Weise erforderlich machen.
- Das Gesamtsystem ist viel zu komplex, als dass es von einem
Einzelnen bearbeitet werden könnte; daher befasst sich eine größe-
re Arbeitsgruppe (ein Kurs, ein Jahrgang ...) mit der Beschreibung
der Verantwortung des Ganzen und definiert daraus die möglichen, notwendigen
und auf dieser Stufe der Kenntnisse bearbeitbaren Teilaspekten für kleinere
Gruppen; das von ihnen bearbeitete wird später wieder zusammenge-
setzt und dabei insbesondere auf seine Verträglichkeit mit dem von
den anderen Gruppen Projektierten und auf seine möglichen zukünfti-
gen Folgen hin überprüft.
- Die Arbeitszeit des Einzelnen ist aufgeteilt nach verschiedenen
Perspektiven: Er lernt hierarchisch geordnete Details, theoretische
wie praktische, die ihm helfen, die komplexeren Aufgaben zu lösen;
er erfasst komplexe Details, die ihm helfen, seine beruflichen
Zielvorstellungen und die darauf gerichtete Spezifizierung im
Hauptstudium genauer zu erkennen und zu formulieren; er sieht eine
Spezialisierung auf sich zukommen, die ihm die Augen öffnet für die
Notwendigkeit, mit anderen zusammenzuarbeiten und damit breitere
Kontakte jetzt schon aufzunehmen, um nicht später betriebsblind und
umwelttaub dazustehen.

b. Aus der Sicht der Lehrenden

Die Lehrenden einer solchen Ausbildung sind dabei in diesen Pro-
zess genau so eingebunden wie die Lernenden, natürlich mit erheb-
lchem Vorlauf für die Auswahl des geeigneten Systems und die dar-
auf zugeschnittenen besonderen Bedürfnisse an Literatur, Experimen-
tiermaterial, Bereitstellung von arbeitsplätzen.
Insbesondere aber gilt:
- Jeder muss einen Teil seiner für die Lehre verfügbaren Zeit
abgeben und daher einen Teil (Ballast-)Wissen auf seinem Gebiet ab-
werfen, damit insgesamt Zeit für gemeinsame Arbeit bleibt; dies er-
fordert Abkehr vom bisherigen Fachanspruchsdendenken und darüber
hinaus Mehrarbeit in der Neugestaltung der Curricula.
Jeder Muss ein Stück aus seinem eigentlichen Specialgebiet heraus - und über die Nahtstellen zum Nachbarfach hinausgehen, um die Anschlüsse sicher zu gestalten; dies erfordert Mut und Lernen auf ungewohntem Gebiet.

Jeder muss in viel höherem Masse als bisher seine Lehrinhalte und -methoden offenlegen, muss sich auf die anderer einlassen und muss schliesslich auch Mehrheitsentscheidungen über gewählte exemplarische Projekte mittragen; dies erfordert eine meist ungewohnte Transparenz der eigenen Handlungen und Ein Demokratieverständnis, das über die übliche Gremienmitarbeit weit hinausgeht.

4. DIE ANORDNUNG DER AUSBILDUNGSELEMENTE

Die in Kap. 2 benannten Forderungen sind gewiss schon mehrfach erhoben worden, auch die in Kap. 3 gemachten Vorschläge zur Durchführung haben verschiedene Ansätze zur Realisierung erlebt. Ersteres hat mich nicht von der Pflicht entbunden, sie noch einmal mit wachsendem Nachdruck ins Gedächtnis zu rufen, denn die Gründe für eine Umstellung haben nicht ab- sondern zugenommen. Das zweite hat uns Lehrende im Fach Technik am Oberstufen-Kolleg nicht bewogen, in die Resignation mancher am Projektunterricht missglückten Ausbildung einzustimmen, sondern uns ermahnt, stückweise Verbesserungen in der erforderlichen Richtung vorzunehmen und auch gegen Widerstände aufrechtzuerhalten.

Nach einer bald achtjährigen Erforschungsphase, mit zum Teil intensiver Unterstützung durch die Stiftung Volkwagenwerk, nach der Erprobung einiger kleinerer Projekte innerhalb der Lehrgebiete einzelner technischer Disziplinen und nach mehrjähriger Erfahrung in fächerübergreifenden, vielfach auch nichttechnischen Projekten, haben wir eine Ausbildungsstruktur entworfen, die den Darstellungen im Kap. 3 in möglichst vielen Teilen entspricht.

Teil der umfangreichen Vorarbeit war dabei eine möglichst detaillierte Beschreibung der Lehrinhalte und -ziele aller Veranstaltungen des Studienganges mit Verweisen auf gegenseitige Bindungen und Voraussetzungen.

In Kenntnis dieser Kursdaten wurde beschlossen, etwa ein Viertel der Zeit des 2. und 3. bezw. des 6. und 7. Semesters zu zwei Projektzwecken in Prozesse, die so über je ca. 100 Arbeitsstunden verfügen. Die Aufgabenstellungen für die Projekte werden dabei an eine Reihe von Bedingungen geknüpft:
- Sie müssen im Einklang mit dem jeweiligen Stand der mathematischen, physikalischen und ingenieurwissenschaftlichen Kenntnisse stehen, sie möglichst intensiv nutzen und so ihrer Verfestigung dienen;
- sie sollen für die Mitglieder der beiden Studienrichtungen Elektrotechnik und Maschinenbau, deren Integration ein Ziel des Studienganges ist, gleichermaßen wichtig und attraktiv sein, vornehmlich also aus den Bereichen Energietechnik oder Verkehrstechnik stammen;
- es sollen Themen bezw. technische Produkte sein, für die es in
der öffentlichen Diskussion bereits deutliche PRO- und CONTRA-Positionen gibt, so dass die im Verlauf des Projektes diskutierten Varianten nicht nur auf ihre technologische Machbarkeit, sondern ebenso auch auf ihre ökologischen Wirkungen und auf ihre gesellschaftliche Wünschbarkeit überhaupt befragt werden können.

5. ÜBERSICHT ÜBER BISHER DURCHGEFÜHRTE PROJEKTE

Als Vorlauf für die in Kap. 4 beschriebenen, umfangreicheren Aufgaben wurden in den letzten Jahren eine Reihe kleinerer Projekte mit sowohl fachinternen wie fachübergreifenden Arbeitsgruppen durchgeführt:

- Projektierung, Bau und Erprobung einer Sonnenkollektor- und einer Solarzellenmessanlage;
- desgleichen von Windturbinen mit verschiedenen Rotordurchmessern bis 4 m, mit Blattverstellung zur Drehzahlregulierung, Generator und Schleifringübertrager, montiert auf ausfahrbarem Arbeitsmast;
- stufenweise Verbesserung von Messgeräten für die Werkstoffprüfung (Härte, Elastizität, Knicklast, Wärmeleitfähigkeit, elektr. Leitfähigkeit von Kontakten;
- Funktionsberechnung, Bau und Messung eines Bevölkerungsmodells mit Einstellmöglichkeiten für Geburten- und Sterberaten und Differenzierung nach drei Altersklassen.

Die meisten Projekte wurden nacheinander von verschiedenen Gruppen bearbeitet, so dass auch die in der Realität unvermeidbare Arbeitsteilung und damit Konzentration einzelner Kleingruppen auf wenige Details erfahren und auf seine Wirkung hin untersucht wurde.

6. LITERATURHINWEIS

Die in diesem Beitrag genannten Analysen, Begründungen, Entwicklungsstufen des Studienganges und vorläufigen Ergebnisse sind ausführlich in den nachstehend genannten Texten beschrieben, die zusammen etwa 8 Jahre Curriculumentwicklung beinhalten:

Asdonk, Küster, Wild (1981), Abschlussbericht zum Projekt 'Integriertes Grundstudium Ingenieurwissenschaften' (Veranstaltungsbeschreibungen, Überlegungen zur Technik-Systematik, Berichte zu einzelnen Projekten, Reader zur Energietechnik); typografisches Manuskript, Oberstufenkolleg, Universität Bielefeld.
In 1972 SEFI was launched at Delft, The Netherlands. The objectives of this non-governmental international organization are to discuss systems of engineering education and training throughout Europe, to analyse and study problems created by the rapid developments in science and technology and to contribute to the development and improvement of the education and training of the engineer by adapting it to the needs of the contemporary industrial world. SEFI has members in twenty European countries.

As the central theme of the annual SEFI Conference of 1982, held at the Delft University of Technology, The Netherlands on occasion of its tenth anniversary was chosen 'The Education of the Engineer for Innovative and Entrepreneurial Activity'.

Rather than analysing these concepts in more detail, the main objective of the Conference is to discuss the relationship between engineering education, innovation and entrepreneurship.

The four main themes of the conference are: Engineering Education and Technological Entrepreneurship, Innovation Centres, Continuing Education and Academic-Industrial Liaison.