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University–Industry Instructional Collaboration: A Model for Continuing Education and Retraining in Engineering*

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A company collaborates with a university to set up a retraining course for a group of engineers and technicians when a composites division is formed. The article outlines the process used to set up the initial course as well as the professional videotape series that was later based on it. Although the course described is specifically on composite materials, the process is intended to serve as a model for continuing education in any field that is 'at the margins' of a developing technology.

INTRODUCTION

THE NEED for continuing education in engineering is growing as the rate of technological change in industry accelerates [1]. A National Research Council Panel on Continuing Education report suggests that even if the direction of an engineering career changes very little—from design to engineering management, for example—the technology it deals with changes rapidly. Continuing education programs can significantly enhance an engineer's ability to contribute 'by promoting creativity, by preventing obsolescence in an era of technological change, or by imparting new skills so that the engineer becomes more flexible and can contribute in areas of need' [2].

A 1989 study by the Office of Technology Assessment (OTA) points out that problems of supply and demand also contribute to the need for retraining and continuing education. Because students tend to base decisions about academic majors on the current job market rather than on potential future opportunities, the supply of new graduates is often out of sync with the demand. Options for increasing the supply of engineers include both retraining and upgrading the education of technicians and technologists [3].

Continuing education is also needed because an undergraduate degree in engineering, despite co-op programs and other practical components, is not designed to prepare the student for a specific job in industry. A four- or five-year bachelor's degree in engineering lays the groundwork for students to go on to graduate school or practice engineering and then to continue expanding their knowledge through lifelong learning and professional development courses; it is not intended as vocational training [4].

It is evident, then, that continuing education is vital for engineers. What is less clear is who should provide those programs. Some would argue that universities are in the best position to provide the needed location, information, and quality control, as well as a sense of neutrality [5]. Unfortunately, providing continuing education is seldom viewed as a vital component of the academic mission. Industry, on the other hand, has a strong motivation for wanting such programs but may lack the resources to provide them. Industry also has an interest in ensuring that such programs are targeted to their needs; research shows that engineers are chiefly interested in continuing education courses that help them to do their current jobs better [6].

The issue becomes further complicated when continuing education must be provided in areas that are 'at the margins' of developing technologies—fields like composite materials, in which only a minority of employees have had formal training. And ironically it is in such areas that continuing education and retraining are needed most urgently. An OTA report on advanced materials

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suggests that the expanding market opportunities for ceramics and composites will require more scientists and engineers who have broad backgrounds. However, only a few universities now offer comprehensive courses in these areas. Thus, there is a tremendous need for continuing education and training programs for industrial engineers and designers unfamiliar with new materials and how to process them [7].

BACKGROUND

For many of the reasons outlined above, the question of effective technical training within a corporate environment was raised when the Du Pont Company created a Composites Division within the Company's Fibers Department several years ago; the new division resulted when the efforts of several small groups of independent researchers were consolidated. All had an interest in composite materials, but only a few had formal training; the remainder came into the group as chemical engineers, chemists, mechanical engineers, and electrical engineers. Each one had a 'piece of the pie', but they needed a formal program to enable them to see how their pieces fit with others.

The answer to the problem was found in a collaborative program. The Du Pont program manager realized that the expertise needed for an effective training program had to come from two sources: (1) academia, where faculty teach engineering fundamentals and where developing and keeping up with new theory and applications are integral to the academic philosophy; and (2) industry, where new design and manufacturing processes, software development, and adaptation are the 'corporate bread and butter'. Based on this realization, the program manager at Du Pont generated a tentative outline of program topics and shared it with the director of the University of Delaware's Center for Composite Materials. The director, in turn, discussed it with several faculty members who had relevant expertise.

Both the program manager and the center director recognized that (1) the required talent and knowledge were shared by about a dozen university faculty and an equal number of corporate engineers; (2) many of the engineers who would be designated instructors had no teaching experience of any kind; and (3) the faculty members from the university had more than adequate teaching backgrounds but little or no experience in providing instruction for working professional engineers. All of these factors were considered as the details of the course were worked out.

PROCEDURE

An instructional development specialist with experience in both higher education and industry was hired to help in delivering instruction, performing a program evaluation for mid-stream corrections to the project, and conducting a program evaluation to recommend how the company could interact with academic institutions in the future.

Instructional teams of approximately half a dozen members each were organized. Two were located at corporate sites, one site involved primarily in manufacturing and the other in design. Two teams were based at the center, one team involved primarily in theory and fundamentals and the other in projections for future technology. Members of each team were designated to attend meetings of the other teams to ensure content integration and continuity.

'Cultural' differences between the two groups had to be considered at this stage. There was a realization that faculty might be perceived as too theoretical, while corporate engineers might be uncomfortable with the idea of teaching. Faculty members might need encouragement to participate in the instructional design process and to consult with colleagues on the development of their sessions. Thus, it was important at this stage to allow corporate instructors to choose their level of participation and to issue caveats to faculty members accustomed to teaching in an academic setting: for example, *Don't reproduce pages of text on overheads* and *Limit the time you spend deriving equations that can be found in textbooks*.

As an initial step, the teams addressed three basic instructional design questions:

- What do you want the participants to get? (content)
- How are you going to help them get it? (process)
- How will you know they have it? (test, assessment)

As the teams met, they designed units of related material in large chunks with several instructors. For example, instead of 4 h/person, they planned 20 h with five people. The general result was to produce greater coordination and integration of the content with a corresponding decrease in overlap and duplication. One of the advantages of this approach is the ability to see decisions related to curriculum and instruction as open for discussion. The following were some of the questions the teams addressed:

- What material is of most worth, why, and to whom?
- How can it be sequenced effectively to ensure logical continuity and integration?
- Should the material be covered broadly or should selected material be covered in depth? How much detail is it possible and/or useful to include? (For example, if it takes 200 h of hands-on experience to learn how to use a software package, how much can be accomplished in 4 h?)

- What kind of balance should there be between dealing with the needed theoretical/conceptual understanding and providing and working through practical examples?
- How can useful discussion and participation and generally more active learning be encouraged?
- How can understandable and useful audio-visual materials and hand-outs be produced?

The teams met every other week for a couple of months. After the first three meetings, recommendations were made to (1) shift some content among the teams, (2) eliminate some sessions, (3) combine some sessions, (4) generate some new sessions, and (5) resequence some of the material. At this point, a content outline with a schedule was generated and distributed to potential participants.

In addition to coherence, integration, and sequencing of the material, permeability was a key concept in the design process. *Permeability* signifies flexibility and a willingness to break expected boundaries. The instructional teams were permeable, with members participating in the work of other teams or even shifting membership in some cases. The instructional design process itself was permeable, allowing the interplay of planning, teaching, and testing. The composites design process, which is, in effect, the content of the program, was permeable as a result. That is, design, development, manufacturing, product testing, and so on were conceived and acted upon as interactive and capable of enhancing each other.

As the work of the instructional teams continued, discussions became increasingly detailed and focused on individual sessions. Team members provided feedback to each other on the appropriateness of their material in terms of the interest and background of the participants, the level of difficulty, and the balance between theory and application. Concern turned to presenting material, engaging participants in the instructional process, and obtaining feedback on effectiveness. Feedback from the participants and systematic observations by the instructional development consultants were used to adjust the sessions remaining in the sequence. Participant attendance and interest were maintained at high levels throughout the course.

FOLLOW-UP

After the 'live' version of the course was over, representatives from both the university and the company realized that a great deal of valuable information had been compiled, much of which could be used by other companies whose employees needed retraining. A decision was made to produce a professional development videotape series (Fig. 1). The lectures had already been taped so that the faculty could critique their own presentations; at this point, those tapes were edited and the final versions made.

Workbooks were then written to accompany the tapes, providing printed material to assist the viewer in understanding and to ease notetaking. The workbooks included video text screens, together with the charts, graphs, and other visuals presented on the tapes. The workbooks became an important component of the course, particularly if it is taken as an axiom of continuing engineering education that participants expect to leave a course with excellent notes [1].

The series, entitled *Introduction to Composites*, was made available to the composites community through the University's Division of Continuing Education. The 22-tape series covers a wide variety of subjects in the field of composites; lectures on basic concepts in materials science, mechanics, design, and testing provide the foundation for more advanced lectures on interlaminar fracture, nondestructive evaluation, thermoforming, and numerical methods in composites processing.

Updating is a critical component of continuing education, regardless of the medium. ASME has found that the average lifetime of a successful course is three to five years [1]. To update the series, six additional tapes based on Center-sponsored composites workshops were added later. Since *Introduction to Composites* was issued, 16 companies have bought the tape/workbook sets, two have bought the workbook sets, and nine have rented tapes.

The series is also going international. Three companies in Singapore have been set up to distribute the course, and tapes have been sold to organizations in Belgium and Japan. In addition, AMCEE (the Association of Media-Based Continuing Education for Engineers) has listed the course in its catalog, which is distributed throughout the world.

SUMMARY AND DISCUSSION

No matter how talented the workforce in a given company, supplemental instruction is almost always valuable. Some people may have extensive knowledge about design but little about manufacturing. Furthermore, the modern integrated systems approach is based on the recognition that all members of a team need to work together at all stages of a problem. And, since working with composites requires design of not only a component but also the material itself, cooperation on a project is essential from the outset.

In a list of developments that are likely to affect the careers of engineers during the period from 1990 to 2000, the NRC Panel on Continuing Education report includes the requirement for a multidisciplinary approach to engineering. The panel points out that new technologies are obscuring the lines beteen such engineering functions as design, manufacturing, marketing, and management [2]. In short, it is not sufficient for people to know only their own jobs; they must at least be

Fig. 1

familiar with those of their colleagues. All of these factors provide a cogent argument for the need to update repeatedly the education of people working in a field like composites.

Offering training in a videotape format can be less expensive than sending employees to short courses, particularly if large numbers of people require instruction. The OTA report on higher education mentioned earlier recommends the use of new education technologies, including video-based systems, to reach engineers at their workspace cheaply and quickly [3]. Video courses enable employees to take such training at convenient times and to complete them at their own pace.

Most of those involved with the development of the 'Du Pont course', whether as students or as instructors, felt that the cooperative nature of the course was a major factor accounting for its success. There is an increasing awareness of the need for cooperation in this area both here and in other countries. In a keynote address at the World Conference on Engineering Education for Advancing Technology in Sydney, Australia, in 1989, Professor P. T. Nicholson stated, 'Whereas the theory can be taught in the classroom or laboratory, the problems in providing practical applications are such that a close association between academics and industrial practitioners is becoming essential' [8]. Although the model described in this article was carried out specifically in composites, the approach and the underlying principles could easily be adapted to continuing education programs in other fields of engineering. The critical component for success was university–industry collaboration at all stages of the process.

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