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An Integrated Problem-Based Learning Model for Engineering Education*

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Traditionally, mechanical and manufacturing engineering degree courses have tended to place too much emphasis on theory, with too little application to the integration of real engineering problems. Further, students have tended to work on their own in tackling problems encountered, thus neglecting the important skill of working in a group and interpersonal communication skills. The authors present a model for a problem-based project, which aims at providing an opportunity for the students to work in groups on a real manufacturing problem and to simulate a situation as if they were employed in industry. A by-product of the project is that students have the opportunity to practise their oral and written communication skills. The problem-based learning aspect of the project is implemented through a design project that involves a typical consumer product. Assessment is an essential part of this integrated problem-based learning approach and this includes four important criteria: individual member assessment, group assessment, leader assessment and tutor assessment. The implementation results indicate that students find the approach more interesting and that it is an effective way of learning.

INTRODUCTION

MODERN MANUFACTURING systems embrace a wide range of applied methodologies and technologies as well as processes [1–2]. The design and operation of modern manufacturing systems requires engineers with multidisciplinary training. The complexity of modern manufacturing means that manufacturing engineers are usually required to work as project co-ordinator in a team. Providing a structural framework for integrating specialist knowledge, they must be trained in such subject areas as mechanical engineering, production engineering and material engineering, supported by elements of computer science and management science. This training is simulated by integrating the processes, machine systems, people, organisational structures and information flow in order to achieve economic manufacturing and competitive performance. Some of the literature [3–5] suggests that the best approach to simulating engineering training is through problem-based learning (PBL). PBL necessitates structuring the curriculum so as to confront students with practical problems thus providing a stimulus for learning. Boud [6], Margetson [7] and Wilkerson [8] suggest that: 'The principal idea behind problem-based learning is that the starting point for learning should be a problem, a query or a puzzle that the learner wishes to solve.' Traditional lecture-based courses have been criticised for their lack of attention to issues such as the integration of topic areas, for placing little emphasis on teamwork, and failing to develop skills of enquiry in students [9–11]. In this paper, the authors propose a model for a problem-based project which is appropriately structured for training engineers in both conventional and distance education.

THE LEARNING MODEL AND COURSE DESIGN

The overall aim of this engineering programme is to provide integrated engineering education and training to honours degree students who intend to seek a career in mechanical and manufacturing engineering. In order to achieve the necessary integration, the problem-solving approach suggested by Cawley [3] should be introduced into the third year or equivalent of their study. It was found that courses, both in conventional and open education, placed too much emphasis on technical theory and too little on the application and integration of real engineering problems. In examinations, students tended to avoid questions of a problem-solving nature even though these are essential to the practical manufacturing engineering environment. The objective is to integrate the various subject areas (manufacturing technology, mechanical engineering, quality and reliability, management, etc.) studied in the degree programme for solving multi-faceted problems. Students are divided into groups of

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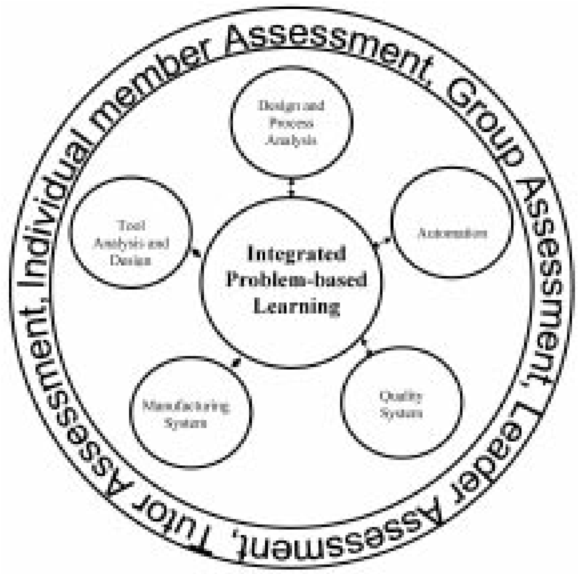

Fig. 1. The five tasks of integrated PBL.

five and work on a group project where they design a manufacturing system to produce a specific product or range of products. In order to achieve this integrated problem-solving learning objective, students are presented with a scenario in manufacturing a prototype product with major sub-tasks including: design and process analysis, analysis and design of tooling, automation, the manufacturing system and the quality system. Fig. 1 illustrates the five tasks which form the basis of integrated problem-based learning. At the commencement of the course, there is an introductory briefing, and, prior to the commencement of each task, there is a detailed briefing. Students are required to submit a report to the project supervisors or course coordinator concerned, and the group leader of each student group gives a presentation at the end of each task. The project is assessed on the basis of the presentation and the report for each task.

The products and tasks

A scenario of a manufacturing firm is set up, and its manufacturing processes consist of five major sub-tasks for students to tackle. Based upon internal and external factors, students are required to make decisions on how the manufacturing firm should operate and how its products should be made. This company is a local manufacturer with typical characteristics that can be found in companies in Hong Kong and China. Its market research department has estimated annual production figures for each product. The company has decided to establish a new factory to manufacture these products, in order to meet the expected demand. The factory has to meet the anticipated demand and has sufficient capacity to meet any increase in production caused by the development of other, similar products. Furthermore, in this problem-solving exercise, the students are provided with different products. The main tasks of this problem-based learning are described below:

- Design and process analysis

The first of the five sub-tasks is 'design and process analysis'. This task is divided into two parts: a detailed design analysis of the product, and its process planning. Students are asked to provide an overall specification for the given product and to produce production drawings of the manufactured components of any one unit. They are required to produce production drawings of those manufactured components which they consider to be most important, with all geometric and dimensions tolerances.

- Analysis and design of tooling

After completing the design analysis and process planning, students proceed to the analysis and design of tooling. This task consists of two elements: an analysis of the tooling required for the production of the components of the product, and a detailed design of the tooling itself. Their analysis must contain detailed descriptions in terms of type, size, form and quantity, with indications of both technical and economic considerations.

- Automation

This task is concerned with an examination of automating the products to identify the potential areas where automation can be introduced to improve productivity. The idea here is to use either analytical and/or lateral (creative) thinking techniques such as brainstorming, analogy, etc., to generate ideas and examine both their technical and economic feasibility. Students are required to describe the proposed automation method and indicate the hardware involved in a form that would be considered acceptable for reporting to senior management.

- Manufacturing system

A manufacturing system operates within the overall context of a supply chain. This supply chain starts with the purchase of raw materials, component parts and sub-assemblies and ends when the finished product reaches the consumer. The effective and efficient use of resources is affected by many factors, both internal and external. Furthermore, it is necessary to tie these together to develop a manufacturing system that is able to produce the required product in the right quantity at the right cost at the right time and of an acceptable quality.

- Quality system

This task is concerned with the design of a quality system to ensure that the product will be produced according to its specifications and that any deviations from this will be identified early in the production cycle. It is particularly important that products of unacceptable quality do not reach the consumer. This task is concerned with management of the quality function, assurance of design and manufacturing quality, as well as quality control of the manufacturing processes.

ASSESSMENT METHOD

Assessment is an essential part of this integrated problem-based learning approach. The above tasks are evaluated by four important criteria: individual member assessment, group assessment, leader assessment and tutor assessment. At the beginning of this exercise, student groups decide among themselves who will lead each group. A different student will lead each task, so that all students have the opportunity to be group leaders. The group leader is responsible for organising the individual responsibilities of group members, ensuring that the task makes reasonable progress and writing the report. The group leader is required to write a leader's report, including a log book listing how he/she has organised the work, the number of meetings, the difficulties encountered, how they were resolved, gaining co-operation from team members, etc. In addition, there is the main report, which describes each specific section, including individual reports by all the group members and the group leader that clearly identify the area of work they have been responsible for, so that assessment can be based on the work of individual group members. The group leader is also required to make an assessment of each group member. This must include a grade for each of the duties of each member. This report is kept confidential. The group leader also makes a self-assessment on his/her performance. This should contain the duties he/she has performed and a grade.

As mentioned earlier, all of the group members are responsible to the group leader for the particular task that has been assigned to them. They are required to carry out the necessary work and write the relevant section of the main report. In doing this, they must ensure that their contribution is in the standardised format agreed by the group. Furthermore, all group members appraise the performance of their respective group leaders as well as providing an individual assessment on their own performance, including an overall grade.

Staff members will attend the oral presentation and study the reports (the group leader's report and the main report). The oral presentation will be delivered by the group leader and should take about 20 minutes. However, other individuals may be involved in this, particularly when answering questions about individual aspects of the work. Generally, there will be five students per group, but the number of students in a group may vary depending on total student numbers. Each group will consist of the same members throughout the academic year. Since the project comprises five tasks, there will be an introduction to the project prior to the first task. After the fifth task is completed, there will be an overall review. A detailed schedule is given to the students. All students are required to take part in the presentation, each with a time slot of 30 minutes (20 minutes for the presentation and 10 to allow for questions). All groups must submit their reports, individual assessments and group assessments before their presentation.

DISCUSSION AND CONCLUSION

At the end of the course, the students are asked to complete a comprehensive evaluation questionnaire with a set of questions that cover each aspect of this subject. The response has indicated that the PBL approach is very satisfactory and the objectives of the training are met. The majority of students appreciated and enjoyed the problem-solving approach, because it stimulated them to tackle the problems using knowledge gained in the early years of their studies. However, some students commented that they were not able to complete all the problems and that they felt that the subject was more time-consuming than a conventional course. It was generally agreed that the problem-solving approach is more interesting and provides an effective way of learning. The study groups played an important role in the integration and application of engineering subjects that have been learned previously. The supportive atmosphere established in the group encouraged interaction and decision-making activities, and hence promoted motivation, communication, creativity, flexibility and adaptability, all of which are essential for an engineer to be successful in industry.

Past experience had shown that there was too much emphasis on technical theory and too little on application to real engineering problems. As a result, in examinations, students tended to avoid questions of a problem-solving nature, even though these are essential to the practical manufacturing engineering environment. In this paper, the authors have proposed an integrated problem-based learning model for the training of manufacturing engineers. The teaching material for a conventional course is converted into a problem-based learning format, which develops the professional knowledge of the students to learn to solve practical engineering problems. A scenario of a manufacturing company is presented, and its manufacturing processes are divided into five major sub-tasks for students to tackle. Based upon internal and external factors, students are required to make decisions on how the manufacturing firm should operate and how its products should be made. The design and development of this problem-based learning approach has overcome the major obstacle of conventional lectures, which do not provide the students with the integration and practical engineering problems that are faced in the industry. The majority of students appreciated and enjoyed the problem-solving approach, because it stimulated them to tackle the problems using knowledge gained in the early years of their studies.

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