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Teaching Manufacturing as Law/Medicine*

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Though the requirements of manufacturing education have changed significantly in recent years, the methodology of teaching manufacturing has not changed much to cope with this trend. In this paper, a novel approach for teaching manufacturing engineering/technology is suggested. The approach is similar to the one practiced in law or medicine where case studies are the vehicle for discussion. Teaching methods at law/medicine schools form the basis for a new manufacturing lab course offered at the authors' university. The course hovers around a typical manufactured product whose design, production, marketing, and management functions are covered to demonstrate the concept behind computer integrated manufacturing.

INTRODUCTION

THE enormous changes manufacturing is going through at the present time have renewed interests in its education. This is especially so in the case of graduate programs offering MS and PhD degrees. In keeping pace with the changes taking place in technology, such as CAD/CAM, robotics, FMS, and now CIM, college/university faculty need to work tirelessly to ensure that manufacturing curricula fulfill the needs of the graduates at the work place. New techniques based on innovative ideas are needed to teach these emerging technologies. Rather than teach these as isolated courses, more 'capstone' courses need to be offered to illustrate the concept of computer integrated manufacturing (CIM). In this paper, the development of a manufacturing lab course based on a novel idea is presented. This new course illustrates the monolithism of manufacturing. It may serve as an alternative to expensive lab resources for supplementing the classroom learning of manufacturing engineering/technology students.

THE CONCEPT

The concept behind the lab course is the premise that if law and medicine can be taught effectively through case studies and real world scenarios, then why not manufacturing?

In order to illustrate the concept on which this paper is based, a review of the methods by which medicine and law are taught is first presented.

Teaching in medical schools—a typical example

Most of the teaching methods in medicine are characterized by what is known as 'activities'. Student participation in the laboratory and in the clinic are the basis of instruction. In anatomy, for example, the adult cadaver on which dissection is performed allows intelligent experiments [1] for learning physiology, pathology and bacteriology.

Students are taught to assimilate data in two phases. In the first phase, data are collected indirectly through microscopic examinations of excretions, secretions, tissues etc. In the other phase, they gather data through physical examination of, and conversation with, the patient. This way he/she learns to enhance data that lead to therapeutic measures for ascertaining and inferring conditions which are likely to be responsible for the disturbance he is trying to quell or ascertain. The student is also required to participate in the conduct of the hospital. In each department he serves as an appointed novitiate following his cases from start to finish, from recovery to autopsy. During surgery, the student helps to set up the equipment, takes part in the actual operation, conducts the examination, observes the procedure closely and at the end cleans up as well. Clinical teaching thus tends to concentrate more in the amphitheater

Thus the students in medicine learn through participation so that they can appreciate the materials covered in lectures. Through study of corpses, they are exposed to the environment in which they will later work. Teaching of manufacturing can, and should, follow similar approach as far as practicable. The present paper describes an attempt in this direction.

Case studies—the basis of learning law

Law schools follow the case-study method of instruction. This approach builds up [2] a hypothetical case around which most discussions related to the topic take place. Only the facts having a material bearing upon the legal issues of the parties are included. The educational concepts evolve through the case methods when the

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instructor varies the manner of handling the cases. He may begin with a statement of the issue by a student, or by putting hypothetical facts which vary only in immaterial details from the case in the text. As the discussions proceed, he may submit divergent fact situations. Students are encouraged to think, to discriminate, to make an evaluation on the fairness of the decision, and to arrive at their own conclusions about the case. At the end, the instructor reports on the verdicts reached by other courts as well as whether the doctrines evolved have been modified by statute. Students are therefore, able to discriminate between the relevant and the irrelevant facts of the case, and gain competence in grappling with new problems. When the student has grasped the principles through the study of cases, he can apply them effectively in the real world.

Thus, the teaching of law through case studies prepares students to review the situation, cross-examine the parties, analyze facts and information, and thus weigh/deduce the authenticity of a case. They become diligent, capable and aware of the things to anticipate, and to reason. In short, the study of law is primarily data gathering, their analogies and presentation to support the case in question. Manufacturing also involves data gathering, their analysis, and judgement on the options available, as demonstrated in the lab course on which this paper is based.

A new approach for teaching of manufacturing

A new approach for teaching manufacturing is suggested in this paper. It is based on the practices at law and medical schools as discussed in the above two subsections. The relative similarities and differences between these and the one developed for manufacturing are illustrated in Table 1. The criteria for comparison are listed in the first column of this table. On the basis of teaching methods, education of medicine is primarily clinical, that of law based on case studies, and of manufacturing lab-oriented. Other comparisons are based on subject and data acquisition. On the basis of the variety criterion, medicine is less complicated since the human body by its very nature is limited in variety. In contrast, the law and manufacturing are complex. Manufacturing encompasses a much larger variety as products/processes differ from each other quite significantly. This variation provides a challenging experience both to the instructor and the students in developing technical and innovative skills.

Why a laboratory course?

The teaching of manufacturing could be made more effective by adopting the methods used in law and medicine. Conventionally, courses are designed to focus on one aspect of manufacturing, such as computer aided design (CAD), robotics, quality assurance, production and inventory control. Even when lab courses are taught to supplement the lectures, these concentrate on one aspect only. While the conventional approach allows zooming in at a particular aspect of manufacturing, it does suffer from the lack of providing a complete view of manufacturing. Thus, the needs of modern manufacturing as dictated by computer integrated manufacturing (CIM) concept is not being served. This has been a weakness of the current practice of manufacturing education.

In the light of these discussions, it was felt that law/medicine type approach is likely to succeed through a lab course. A new lab course was therefore designed for teaching manufacturing in a structured way so that students can learn to address the various manufacturing issues around a typical product that serves as a candidate. A lab course

Table 1. Comparison of the teaching methods: Medicine, Law and Manufacturing

#	Criterion	Medicine	Law	Manufacturing (as per the concept of the paper)
1	Teaching method	Clinical and through examinations	Case studies	Laboratory course
2	Subject	Corpse or patient	Hypothetical cases	A typical manufactured product
	Data acquisition	Directly collected from the subject or through laboratory testing	Derived, assumed and presented	Measured, derived and assumed
4	Variety	Limited (Humans and mammals)	Numerous (Cases may differ)	Wide (several manufacturing processes & materials to choose from, variety is also due to new developments taking place)
5	Objective of Instructor	To teach principles	Same	Same
6	Professional objective of student	To diagnose and cure any ailment	To judge the authenticity of a case	To contribute towards enhanced manufactured products

rather than a lecture course is selected since lab environment is conducive to studying all interacting aspects of manufacturing a product. The new lab course is independent of any other course and aims to imitate a manufacturing enterprise. The experiments were designed so that they have enough interaction with each other as explained below.

THE COURSE

A typical manufactured product has been selected as a candidate for the course. The portable power saw (briefly described in the Appendix) shown in Fig. 1 was chosen since it comprises a number of parts that are representative of a variety of manufacturing materials and processes. It is neither too simple nor to complicated, and is a good example of a discrete manufactured product. The various parts are shown in Fig. 2.

A new lab course based on the concepts elucidated in this paper is being offered during 1990–91 in the MS degree program [3] at the University of Southern Mississippi. As a two-credit hour course spread over one semester (15 weeks), the MFG 670L meets once every week for four hours. The course comprises 13 experiments [4] as listed in

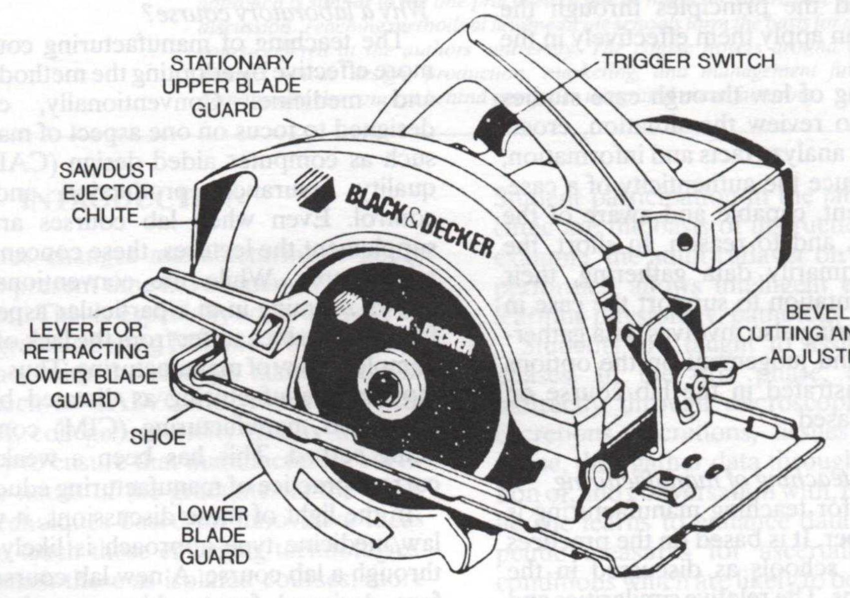

Fig. 1. The candidate product—a portable power saw.

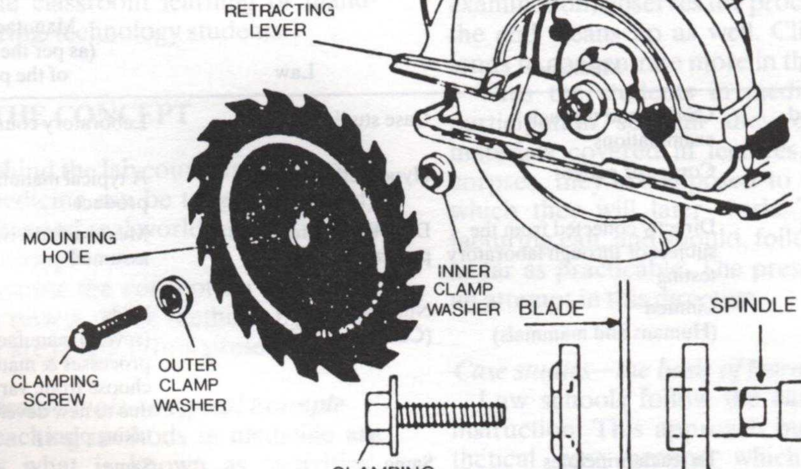

Fig. 2. Assembly drawing of the product.

Table 2. The experiments cover advanced topics of manufacturing with the special feature that all of them hover around the candidate product. The interaction amongst these experiments are illustrated in Fig. 3. This figure represents the thrust and the novelty of this course which aims at making students appreciate the concept behind CIM.

The students are introduced in the first meeting to the lab course and its uniqueness. Also provided is a physical display of the portable power saw, and later its components. A handbout on the experiments and their schedule is presented to the class. The handout also contains the assumed profile of a hypothetical company where the product would be manufactured. Each experiment is described under the following headings:

Title:

Objective:

Assignment: What is to be done in the experiment?

Procedure: A brief outline of the procedure to be followed.

Table 2 Experiments under MFG 670L course

Expt #	Brief title	Purpose
0	The Course	Introduction to MFG 670L experiments
1	Business	Management and its link with other functions
2	CAD-1	Design and Analysis of a part using finite element method
3	CAD-2	Drafting/drawing using AutoCAD
4	MRP-II	Computerized manufacturing resource planning and control
5	GT	Classification systems and coding of parts
6	CAPP	Developments of a process plan for the part
7	NC	NC code generation using NC programmer
8	FMC	Machining of the part on a machining centre
9	Robotics	Feasibility and justification of using a robot
10	Simulation	Simulation of the process plan
11	CAQA	Design and implementation of a suitable quality assurance program
12	MAP/TOP	Study of MAP/TOP as the nervous system of CIM

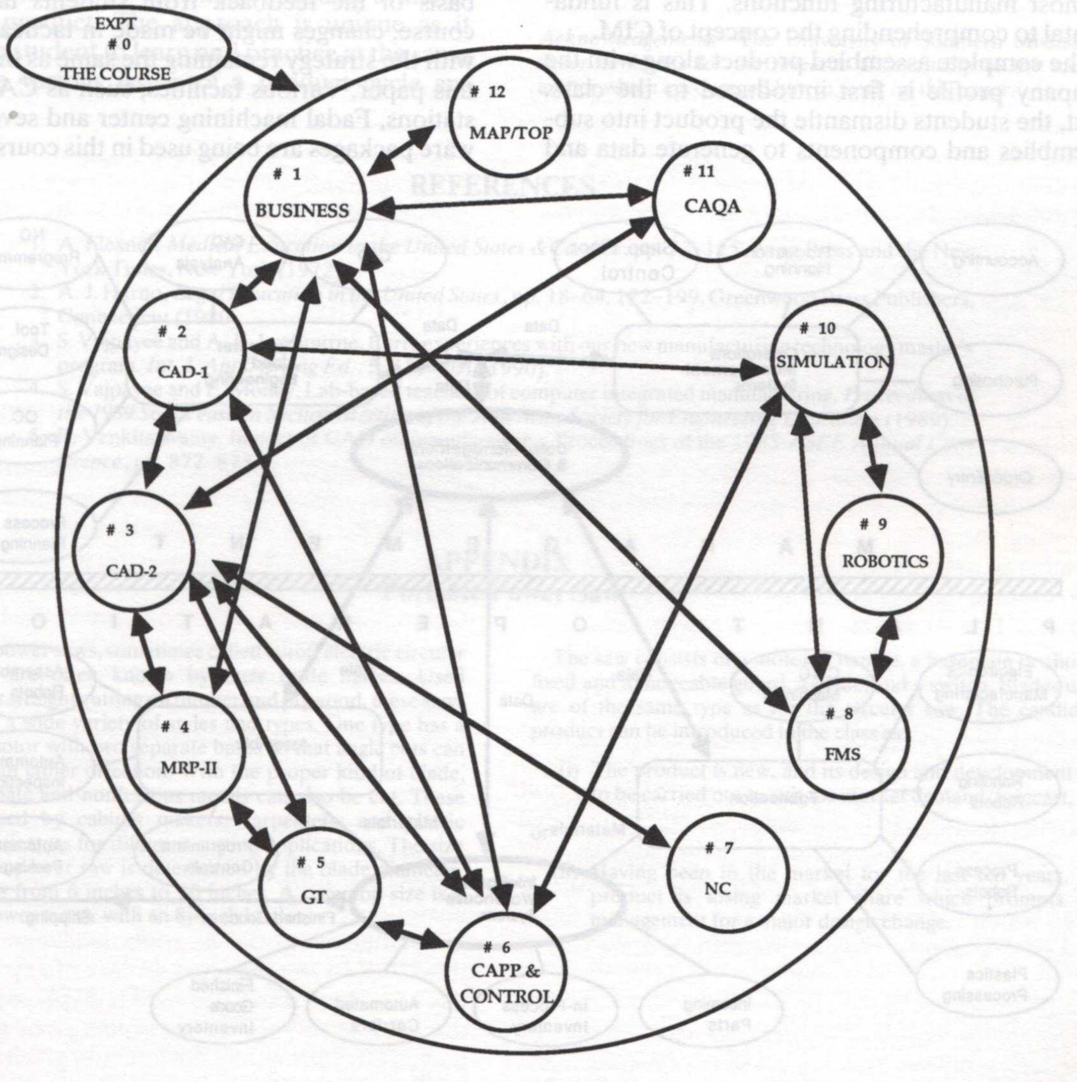

Fig. 3. Interaction amongst experiments.

Results and Discussions:

Report: To be submitted before the next experiment.
(Besides describing what has been learned, the report should contain critical discussions on questions asked at the end of the handout, including how it interacts with other experiments.)

Comments: Here the student is encouraged to make any observation/comment which might enhance the experiment in future.

Resemblance to CIM

The MFG 670L course provides an opportunity for students to learn in a lab environment the various activities of manufacturing enterprise. Students evaluate and analyze product demands, plan production capacity, develop market strategies, design and develop quality assurance plans making use of computers and a CNC machining center. This resembles the CIM concept [5] of organizing and integrating the diverse manufacturing functions as shown in Fig. 4. The lab course may be considered a CIM amphitheater where pertinent data is generated for design and analysis of most manufacturing functions. This is fundamental to comprehending the concept of CIM.

The complete assembled product along with the company profile is first introduced to the class. Next, the students dismantle the product into subassemblies and components to generate data and information necessary for its synthesis. Each subassembly thus forms a corpse on which students may draw process plans, generate design procedures, plan equipment and layout facilities, build forecasting and other computational models, and set up inspection procedures. The vast amount of data so generated forms the data base for a mini-enterprise through which other areas of CIM result. The expertise and guidance of the faculty provides the necessary stimulus for motivating students into working with a well defined objective and a specific goal based on an integrated approach. Students are offered a challenging and creative environment to understand the fundamentals and the gist of manufacturing. Effective use is made of the library and other resources such as computers and sophisticated tools of CIM such as CAD/CAM, FMS, robotics. This results in greater exchange of information as both theoretical and practical difficulties are equally weighed and measured. Students are also encouraged to provide feedback to enhance the experiments.

Feedback

The course is offered once every year. On the basis of the feedback from students taking the course, changes might be made in tactical matters with the strategy remaining the same as outlined in this paper. Various facilities, such as CAD workstations, Fadal machining center and several software packages are being used in this course. As the

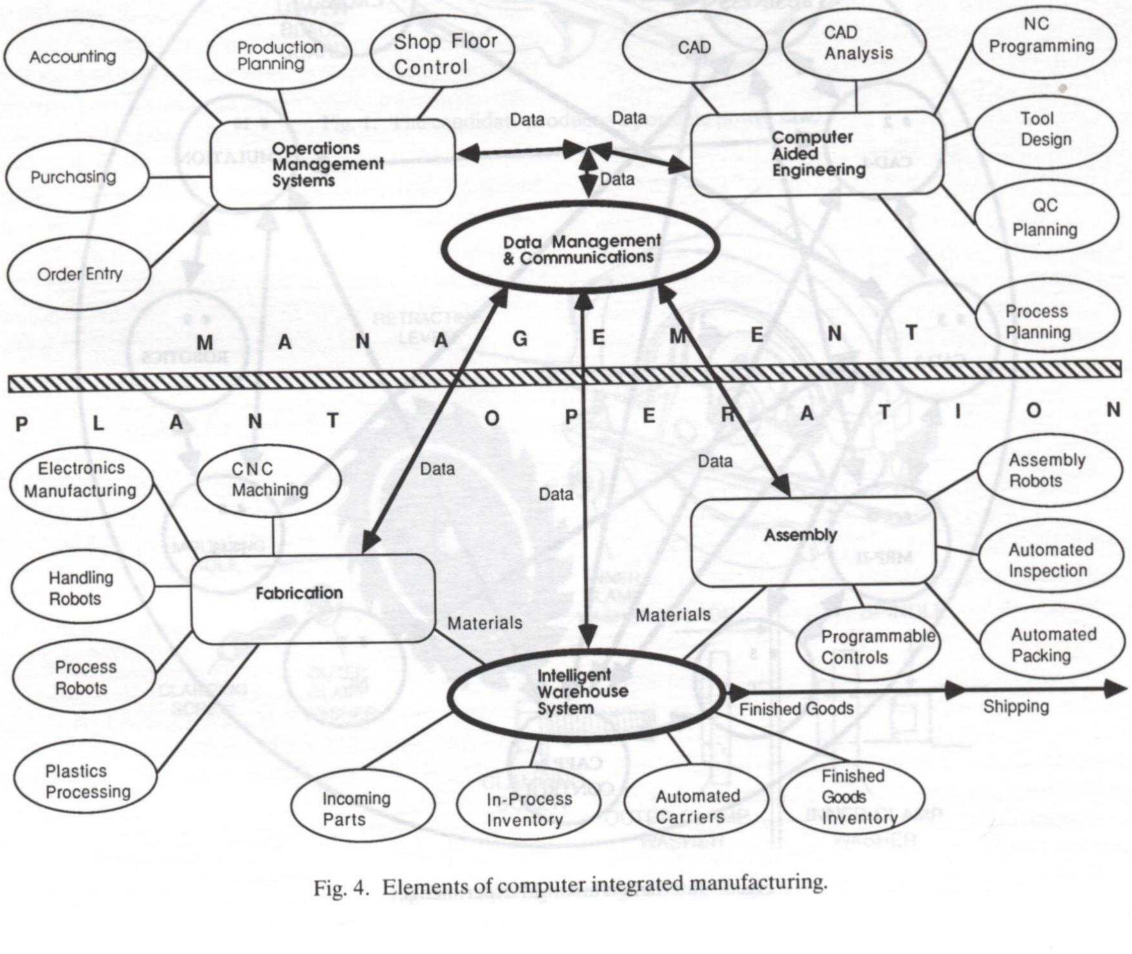

Fig. 4. Elements of computer integrated manufacturing.

facilities expand, the experiments will be modified to exploit these.

Since the students taking this course are working toward a M.S. degree, they will be expected to contribute creatively toward the objective of the course. They will be learning about not only how to carry out the experiments but also how to improve the experiments. This would demand of them self study and literature search outside the formal lab hours.

DISCUSSION AND CONCLUSION

It has been said that a proper understanding of the complex manufacturing environment cannot be acquired solely from text books. Lab-based teaching using case methodology is purported to develop problem solving skills and encourage greater faculty-student interaction. The future of manufacturing depends upon the extent to which students are trained in the methods and tools of manufacturing. The approach presented in this paper demonstrates how manufacturing education can be enhanced by teaching it around a manufactured product. The approach is unique as it allows the student to learn and practice at the same time. The various issues of a product cycle are covered through research and assimilation of data. The students are thus able to utilize their knowledge more effectively and become competent in their approach to seeking solutions.

The methodology of teaching manufacturing through experiments and case study type of approach is intended to imitate a factory environment. As the course evolves during the next five years, students taking the course would in future be designated by titles based on job responsibilities such as design engineer, supervisor or process engineer to appreciate the need of interaction in manufacturing a product. Thus the lab course would eventually resemble the actual industry wherein the engineer-in-training carries out the task assigned to him/her by each department.

Teaching of manufacturing in a way similar to case/corpse methodology offers a unique learning experience to both the faculty and students. The newly developed laboratory course MFG 670L at the University of Southern Mississippi illustrates the idea behind computer integrated manufacturing. Though this course is developed primarily for graduate students, the approach is extendable to undergraduate labs as well.

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APPENDIX
Portable Power Saw

Portable power saws, sometimes called cutoff electric circular hand saws, are often known by their trade names. Used primarily for straight cutting on lumber and plywood, these saws are made in a wide variety of styles and types. One type has a reversible motor with two separate bases so that angle cuts can be made from either direction. With the proper kind of blade, plastic laminate and nonferrous metals can also be cut. These saws are used by cabinet makers, carpenters, and plastic laminate fabricators for different cutting applications. The size of a portable power saw is determined by the blade diameter, which ranges from 6 inches to 10 inches. A common size is a 1/2-horsepower motor with an $8\frac{1}{2}$-inch blade.

The saw consists of a motor, a handle, a baseplate or shoe, a fixed and a moveable guard, a blade, and a switch. Blades used are of the same type as for the circular saw. The candidate product can be introduced in the class as:

(i) The product is new, and its design and development are to be carried out to suit the market demand/forecast,

or

(ii) Having been in the market for the last ten years, the product is losing market share which prompts the management for a major design change.