

Developments in Project and Multimedia-based Learning in Manufacturing Systems Engineering*

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This article discusses the development of an approach to teaching Manufacturing Systems to third-year engineering students at the University of Auckland. Prior teaching exercises at the university employing project-based learning have met with success and the Manufacturing Systems Group has continued the development of its INFOstation concept in 2003 with the delivery of an immersive ergonomics project in a prototype virtual factory. The article outlines the teaching methodology used and describes the ergonomics project and the INFOstation Company in more detail. The results of student feedback are described together with plans for further developments in 2004.

INTRODUCTION

AT THE UNIVERSITY of Auckland, Manufacturing Systems teaching is integrated into the four-year mechanical engineering undergraduate degree offered by the Department of Mechanical Engineering.

Under the current course structure for this degree there is one compulsory manufacturing systems course in year three, and one elective course in year four. As a result, contact hours with the students are restricted, and academic staff teaching these courses find it difficult to adequately expose students to what is considered to be core knowledge for manufacturing engineering and to ensure that students obtain as clear and cohesive a view of the topic area as possible.

In addition to these issues the education of manufacturing engineers sets us two particular and specific challenges. These are the problems of impressing upon undergraduate students, with little workplace experience, the overwhelming importance within the manufacturing engineering discipline of a key resource—*time*, and a key concept—*systems integration* [2].

Unlike some other topics that undergraduate students must comprehend such as mechanics, thermodynamics, or control systems, the issues of *time* and manufacturing *systems integration* are difficult to demonstrate, explore or manipulate in conventional lecture or laboratory sessions.

The first challenge is *time*. Time is a resource renowned for being in short supply and which once wasted can never be regained. Although professionals in other engineering disciplines are subject to time constraints, none we believe, feel

its pressures more strongly than manufacturing engineers. In practice manufacturing engineers are under constant pressure to meet production targets and delivery schedules and to ensure that maintenance and commissioning activities keep to schedule in order to reduce, or eliminate, disruption to normal production activities.

Undergraduate students are given a solid background in the use of resources such as materials and space, but much less experience comes their way to help them understand the best use of time and the crucial importance of time management.

Impressing these issues on students is not an easy objective to meet since competing demands on students' time mean that it is not realistic to expect them to solve production-halting problems in 'real time'. We cannot expect them to 'down tools' on other assignments whilst they deal with a very short timescale manufacturing systems assignment.

The 'INFOstation Company' project will attempt to deal with the time issue by emphasising, in the students' dealings with the virtual company, the importance of speedy and timely decisions, and the cost repercussions of prevarication and poor time management. This is only a partial solution however and more work will be done to simulate this factor in future student projects.

One technique for demonstrating time issues and rapid decision-making is to make use of some form of management game. However these exercises often tend to have a 'one off' feel to them rather than being an integrated part of a student's learning experience over a long period. We will seek to harness the enthusiasm often generated by management games with the interactive, and immersive characteristics of the multimedia virtual company to provide a more thorough solution.

The second challenge is *systems integration*. Systems integration, effectively and efficiently

* Accepted 3 February 2004.

carried out, is the key to the operation of a successful, profitable manufacturing organisation. Today's manufacturing environment integrates a wide range of physical resources from standalone machine tools and continuous flow machines through to raw materials and shop floor computing networks. Less tangible systems such as planning, quality systems and human resources have to be seamlessly fitted into the operation. In manufacturing industries, the processes of product design, systems/project control, and the management of manufacturing operations and equipment are interactive, dynamic and interrelated.

What is required to assist in giving students the capability to grasp the whole picture is a teaching methodology that gives students a global view of how each sub-process combines with others to form a functional whole.

The INFOstation Company project will also aim to assist students to gain a comprehensive understanding of the design, planning and manufacturing processes as complete and integrated entities. It will do this, as the concept is developed, by making the INFOstation Company the metaphor, or scenario, within which a number multi-topic student projects will be placed.

TEACHING MANUFACTURING SYSTEMS AT THE UNIVERSITY OF AUCKLAND

In 1995 the Manufacturing Systems Group adopted a project-based learning approach in order to allow students to get first-hand experience and a 'feel' for actual manufacturing systems and processes whilst at university [3]. Year four students (in groups of three or four) were, with the co-operation of local manufacturers, given actual industrial problems to investigate and solve. This programme has had encouraging results with positive student feedback and significant gains in conceptual learning.

Unfortunately this approach, whilst very useful as far as it goes, does not solve all the problems associated with providing the best possible learning experiences for students. The students discuss their allocated project with managers and others in the host company and learn about organisational structure, communication, note taking, etc. However, they are often not exposed to, or do not have time to explore, the full range of activities in the organisation. Generally speaking the complexities and interlocking operations of a typical manufacturing company are not fully experienced or understood. Clearly something else has to be done.

An appreciation of *time* as a manufacturing resource or constraint is also not generally impressed upon the students during the industry project exercises described above. This is because the 'ideal' student project is one that deals with a problem that the company needs addressed but is not critical for the company's short-term success.

They are often those issues that have been postponed because of a lack of time, staffing or finance, within an organisation. Because of this, the projects rarely have a critical time constraint—at least not of the intensity experienced when dealing with real production emergencies.

Of more concern however, is the fact that this industry-based project approach is obviously unworkable when considering the needs of the preceding introductory year three course in manufacturing systems, which typically has a roll of about one hundred students.

The requirement for this year three introductory course is to deliver the knowledge, across a broad spectrum of manufacturing systems topics, that is required to provide an adequate foundation for later study. It is necessary to deliver it in a way that, as with the year four course, will emphasise to students the interactions, and complexity of systems within a manufacturing organisation.

In recent years, researchers in the field of engineering education have investigated the application of multimedia technologies to the education of manufacturing engineers. Many of these developments have included the use of 'manufacturing games' [4]. These can range in complexity from decision rules incorporated in a spreadsheet, through to real-time games where the students must maintain ongoing contact with the simulation to deal with the evolving progress of the game. These simulations often have suddenly changed ground rules or parameters thrown in by the engineering faculty to keep the students on their toes. Another common approach is to simulate individual shop floor machines by computer 'stand-ins' [5] often using proprietary software such as *Flexsim* by Flexsim Software Products Ltd, *Quest* by Deneb or *Arena* by Rockwell Software Ltd.

With this work in mind, and in order to meet the requirements described above within the constraints of large student numbers and less than optimum contact time, the INFOstation concept was developed [6]. The concept was designed not to mimic the powerful process simulation and 3D graphics capabilities of proprietary software, or to have the student work through a single-issue simulation or game. Instead, the INFOstation Company concept was designed to provide a basic virtual company scenario, which would concentrate on emphasising the interconnectivity of many tasks and processes within a manufacturing organisation. Thus for example, the INFOstation simulation will, as it develops, have within it administrative and financial departments and their associated systems as well as design and manufacturing functions.

When fully developed, INFOstation will be a number of multimedia-based 'modules', each of which will cover a different aspect of manufacturing. Each module will consist of a multimedia-based virtual project which will provide students with the necessary parameters to analyse and solve

an open ended problem, as well as providing comprehensive resources on that particular aspect of manufacturing. Having tried out the concept earlier, a redesigned and more immersive ergonomics project was presented to the students in 2002. This development is described in more detail below.

THE INFOSTATION COMPANY

The INFOstation Company is the virtual manufacturing organisation that will be the core of ongoing development and has a website on the School of Engineering intranet (Fig. 1).

The scenario is of a medium sized manufacturing organisation, with a virtual workforce of two hundred, of which half are engaged in production, the toolroom or maintenance. Eighty staff are administrative including those dealing with accounts, sales and marketing. There are twenty staff in the engineering function which includes designers, manufacturing engineers and QA specialists.

In future developments it is possible that a live connection could be made via the Internet with a real local manufacturer, as suggested by Dessouky and Verma [7].

The company currently encompasses four units—the Design Office, Planning Office, Quality Assurance Laboratory and Administration. Further development will see the addition of several more departments to complete the enterprise.

The courses in which students are exposed to the concept are:

- Year one—Engineering Design 1.
- Year two—Engineering Design 2.
- Year three—Professional Development III and Manufacturing Systems.

THE ERGONOMICS PROJECT

For the ergonomics project, the students are told, through the medium of the company's on-line 'Staff Manual', that the Planning Office is responsible for the efficient planning, maintenance and review of the handling, assembly and machining tasks within the organisation. This responsibility includes ensuring that staff are not required to carry out tasks that may be dangerous, excessively tiring, or detrimental to their health. In order to meet this responsibility the Planning Office engineers must be familiar with the theory and practice of ergonomics as well as the relevant health and safety legal requirements.

This student project is suited to being dealt with using a computer-based method as typically the ergonomics analysis tools used in industry are computer based (ErgoEASE[®] being an example). In addition, transferring a video of the task under consideration to a computer video file (AVI) on a network, allows the students to view the operation when and as often as they require. Digitally 'rewinding', and stepping through the video in



Fig. 1. Home page of the INFOstation Company Limited.

small increments to examine movement and detail, is also much easier than with videotape technology.

After 'joining' the Planning Department the students receive a memorandum from their 'employer', in the person of the Manufacturing Manager, asking them to immediately complete an ergonomic investigation into a handling operation that is causing some concern to both the employee and the union.

The project scenario consists of a real process from industry where an operator performs a sequence of repetitive operations. In this process, the operator removes packs of empty drink cans from a pallet, places them on a conveyor bench and unbundles them. The total job cycle includes removing the packs from a six-layer stack on a pallet resulting in some vertical reaches being above eye height whilst the bottom layer is almost at floor level. Since the packs are three deep across the pallet, the task also involves different severities of horizontal reaches. In industry the analysis of this task would cover the unstacking of the complete pallet load to enable an investigation of the total severity of the task and an estimate of the total energy required to unstack the complete pallet. For this assignment the students were asked to analyse only the most severe motions for the operator during the task.

The objectives of the exercise were:

- to make students aware of ergonomic issues in the workplace;
- to reinforce and extend the material covered in lectures;
- to obtain some hands-on experience in industrial problem-solving and productivity improvement;
- to give students practice in quickly learning (and applying) a new professional computer-based analysis tool;
- to practice the important skills of professional inter-office communication and report writing.

Students accessed, from INFOstation's virtual Planning Office, some ancillary data and a video clip of the operation (Fig. 2) prepared by a virtual colleague. This data included the length of a factory shift, the body weight of the operator concerned and the weight of the load being handled.



Fig. 2. A still from the video.

ErgoEASE[®]

Students used a professional software package called ErgoEASE[®] to perform the ergonomic analysis. The program, using a graphical interface, allows students to input the results of a detailed methods analysis together with general task parameters and produce a range of reports on the ergonomic safety of the operation, the energy expended, etc. The program has a number of detailed graphic help screens to assist students who are unfamiliar with the terminology and acronyms used in this field.

THE PROJECT FORMAT

The text of the memorandum to the students was:

- Please complete an ergonomic investigation into a pallet unstacking operation.
- Analyse the work cycle shown in the video clip including the initial and final reaching and lifting operations. Utilise anthropometric tables to estimate values/dimensions not given.
- Please write a detailed narrative of the video clip. Then enter the handling and motion sub-elements into our ErgoEASE[®] program from your narrative and carry out an ergonomic analysis.
- In your report I would like you to:
 - calculate the maximum kilocalorie rate/minute (from your ErgoEASE[®] results);
 - comment on the ergonomic relevance of the particular lifting cycle you have analysed in the context of the total task of unloading the pallet;
 - complete a Rapid Upper Limb Assessment (RULA) analysis on what you regard as the two most ergonomically sensitive parts of the cycle;
 - sketch up and cost an improved layout/process for this operation;
 - recommend a suitable illumination level for the workspace.

It was suggested to students that, as a competent INFOstation employee, their suggested solution should consider all the usual, relevant industrial issues and constraints, e.g. costings, effectiveness of solution, payback period, downtime, likelihood of staff/union acceptance, legal requirements, etc.

STUDENT ACCEPTANCE

The result of a survey of the participating students was very encouraging. Student feedback also indicated that there were some pedagogical issues to be addressed within the ergonomics exercise.

Some students had difficulty understanding what was required of them. This appeared to be because they were not used to receiving

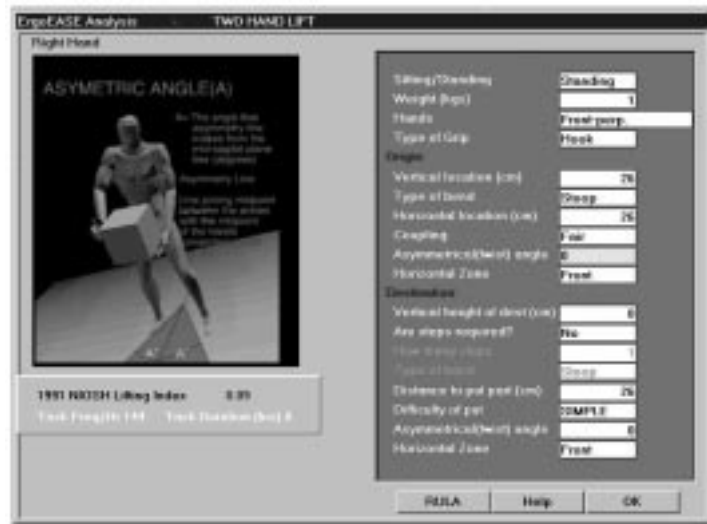


Fig. 3. Sample analysis screen from ErgoEASE®.

instructions, or data, in a narrative form, in this case in the format of a typical company interdepartmental memorandum. Another problem concerned the ErgoEASE® software. Although not difficult to use, students had little time to become totally familiar with it. As a consequence some students attempted to utilise all of the program's analysis modules when only one was required for the purposes of the assignment. This led to some students producing large volumes of printouts that were not required for their report (not untypical of what can happen in industry!).

In general, however, the students felt that the INFOstation format made the ergonomics assignment more interesting and more lifelike. A sample of twenty students were personally interviewed and were unanimous in wishing to have other topics delivered in a similar manner.

FUTURE DEVELOPMENTS

In 2004 the INFOstation Company concept is being extended to include the financial operations of the company. Students will participate in a project that will involve the analysis of INFOstation's cash flow, and financial standing together with a requirement for them to make some financially and technically sound decisions about much needed capital investment. Once logged on, and in the INFOstation environment, students will view a short video clip of the 'Manufacturing Manager' outlining a specific manufacturing problem. Students will then be able to run a video of three presentations by equipment suppliers' representatives outlining the technical and financial benefits of their competing products. Students will be required to analyse the presentations, make notes of important parameters and use the data to produce a report containing a recommendation for purchase together with an analysis of the expected return on investment. This exercise will be a part of an

Engineering Management course in which Manufacturing Systems Students participate.

At this stage it will also be possible to create links between the different topics covered by the INFOstation concept. Projects in first year classes will concentrate on relatively simple design tasks for the INFOstation Company's product range. In subsequent years, these INFOstation products will be used as starting points for facilities layout, ergonomics and work exercises, etc. which are of a more complex nature. In the final year of the undergraduate degree course, project tasks will span a broad range of issues of a high level of complexity and inter-relatedness. For example, solutions to an ergonomics problem will be complicated by INFOstation's production throughput demands, capital expenditure requirements and time and cost constraints. Students will be required to suggest practical compromises between these competing demands.

It is intended to extend the concept (Fig. 4) to include topics such as quality assurance, resource and environmental issues. Later, data linking will be carried out with production and CNC machining simulation software and hardware such as machine tools and a robotic assembly cell.

To support the development of the INFOstation initiative, research will also be carried out into producing an assessment instrument to gauge reliably the effectiveness of the overall concept and of individual modules within it. We wish to discover which topics and techniques benefit most from delivery by this 'virtual company'.

CONCLUSIONS

The staff involved in the INFOstation project and its application to the teaching of ergonomics issues to engineering students believe that the ergonomics exercise was successful. In delivering the topic in a more immersive fashion students felt

Stage 1 Development	
Administration	Design Office
Financial Management Break Even Points Profit & Loss DCF	Design Design for Assembly Value Engineering
Planning Office	QA Lab
Ergonomics Facilities Layout	SQC

Stage 2 Development	
Machine Shop	Assembly Operations
CNC Technology	Work Study
Warehouse	
Stock Control Forecasting	

Stage 3 Development	
Sales & Marketing	Executive Office
Market Research	Resource Mang. Environmental Issues

Fig. 4. Chart of INFOstation departments with corresponding teaching activities.

that it was more ‘realistic’ and more interesting than ‘run of the mill’ assignments. The returned assignments were generally of a high quality with some students really getting into the spirit of the exercise and formatting their results and commentary in the format, style and language they would be expected to use in a workplace memorandum and technical report.

This project, like all new course design initiatives, required some development time by the staff involved but not an unreasonable amount and the time investment is expected to be repaid when the exercise is repeated in following years.

Students learnt a great deal about extracting data and instructions from a wordy memorandum.

This area will be investigated in more detail to examine if any correlation exists between students who have some difficulty with this aspect of the assignment and those students for whom English is a second language.

Also to be developed and tried is a more immersive simulation environment involving a considerably more complex INFOstation scenario. We wish to investigate this area of narrative scene-setting to discover if there is a saturation point to be reached in making the concept real. That is, as far as benefits to teaching are concerned, is there a law of diminishing returns in the application of the INFOstation Company metaphor, and if so, at what point does it begin to apply?

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