The Development of a Multimedia Based Learning Environment for Manufacturing Systems Engineering Students

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Abstract — *The paper discusses the development of a novel approach to teaching Manufacturing Systems to third year engineering students at the University of Auckland. This is achieved through the use of a multi-media based learning system which delivers immersive projects via a virtual company environment called "INFOstation Limited." The INFOstation concept is described within the paper and the multi-media based modules representing typical departments within the medium sized engineering company are explained. The virtual company concept attempts to provide students with an appreciation of the importance of time in an engineer's decision making process and to promote a comprehensive understanding of the process of design, planning and manufacturing as integrated entities. A detailed description is given of a particular real life ergonomics problem in which students were required, by the company's "Engineering Manager," to analyse a materials handling operation for ergonomic impact and to complete a professional quality report on the situation and to recommend any required workspace changes. The paper also details the results of student feedback on the INFOstation concept and describes planned future developments. Part of the ongoing work described, is the development of an assessment instrument to gauge the reliably and effectiveness of the overall "virtual company" concept and of individual modules within it. The intention is to discover if some topics and techniques are more suitable for this learning approach than others and to see if any significant variations exist for students who have English as a second language.*

Index Terms — *Undergraduate students, virtual company, multi-media learning, manufacturing engineering.*

INTRODUCTION

The University of Auckland's Mechanical Engineering Department introduced a course in 1998 on Manufacturing Systems into its four-year undergraduate degree programme. This compulsory course for all penultimate year students has proved to be demanding on the available resources due to increasing enrolments in the Department, and as a result, contact hours with students have become restricted. As a consequence, academic staff involved in the teaching of this course find it difficult to adequately expose students to the necessary core manufacturing systems knowledge required by engineers while ensuring that the students obtain a clear and comprehensive view of the topic.

Of concern to educators involved with these engineering undergraduate students who are studying manufacturing systems with little or no workplace experience, are the dual issues of their understanding of the importance of *time* and *integration* [1]. In practice, manufacturing engineers deal, on a daily basis, with production targets, maintenance schedules, resource limitations and financial constraints, usually under severe time pressures. Furthermore, the inevitable interaction between the departments in a manufacturing company need to be considered in any decision making process. It is therefore essential that the importance of the effective use of "Time" is impressed on students, as well as introducing them to the concept of "Systems Integration."

Although professionals in most engineering disciplines are subject to time constraints, none, we believe, feel its pressures more strongly than manufacturing engineers. In practice, manufacturing engineers are constantly under pressure to meet production targets and delivery schedules, and ensure that maintenance and commissioning activities minimise disruptions to normal production activities.

It is a requirement in today's manufacturing environment that a wide range of physical resources from stand-alone machine tools and continuous flow machines need to be properly integrated. Less tangible systems such as planning, quality control and human resources also have to be seamlessly integrated into the organisation's operations. In successful manufacturing industries the processes of product design, systems/project control, and the management of manufacturing operations are interactive, dynamic and interrelated. Thus, we believe, systems integration when effectively carried out, is a key factor in the operation of a successful and profitable manufacturing organisation.

Most topics that mechanical engineering students study in a typical undergraduate programme, such as mechanics or thermodynamics, concentrate on scientific theory which is relatively easy to comprehend by the use of numerical examples. However, the issues of time and systems integration in a manufacturing systems course are difficult to demonstrate or explore in a conventional lecture or laboratory session.

Although undergraduate students are given a solid background in the use of resources such as materials and space, much less experience comes their way to help them understand the crucial importance of the use of time and the consequences of any decisions made. There is a need therefore, to give students the capability to grasp these concepts through the use of a teaching methodology that gives them a global view of how each individual decision combines with others to form an integrated solution to a problem.

The "INFOstation Company" concept [2] described in this paper attempts to provide students with an appreciation of the importance of time in a manufacturing engineer's decision making process and to provide them with the opportunity to gain a comprehensive understanding of how the design, planning and processing phases within a manufacturing environment, form a complete and integrated system.

TEACHING METHODOLOGY

Eight years ago, the Manufacturing Systems Group within the Mechanical Engineering Department adopted a project-based learning approach for its final year elective course on Technology Management. This was done in order to allow students to gain first-hand experience and a "feel" for actual manufacturing systems and processes whilst at university [3]. Students, in groups of three or four, were given actual industrial problems to investigate and solve. This was done with the co-operation of local manufacturers who participated in the programme. The results of this initiative were encouraging with positive student feedback as well as significant gains in their understanding of the processes of problem solving in real life "dynamic" situations.

Whilst this project-based approach was very successful, it did not entirely solve the problems associated with providing students with the best possible learning experience. Although students had the opportunity to discuss their allocated project with managers and other personnel within the host company and in the process, learned about the organisation's structure, communication networks etc., they did not have the time to explore the full range of activities in the organisation and fully appreciate the complex interaction of job functions and processes within the company.

It was also generally not possible during these projects to impress on students the importance of time as a manufacturing constraint. This was because the ideal student project is one that deals with a problem that the company needs addressed but which is not critical for the company's short-term success. The projects, in general, tended to be those which had been postponed because of a lack of time, staffing or finance within the organisation. Because of this, the projects rarely had a critical time constraint associated with them other than those imposed by the usual university course schedule. Thus, the need to make appropriate use of time by students, was not as obvious as is normally found when dealing with real-life production emergencies.

Of more concern, however, was the fact that this industry based project approach was obviously unworkable if applied to an introductory course in Manufacturing Systems which typically had an enrolment of around one hundred students each year.

The primary requirement for the introductory course, is to deliver essential knowledge about manufacturing systems topics that are needed to provide an adequate foundation for later study of the subject. It is necessary, therefore, to deliver the material in a manner that emphasises to students the complexities, and interactions between departments within a typical 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 following a simple set of decision rules incorporated in a spreadsheet, through to real-time management games where the students must maintain ongoing contact with the simulation in order to deal with the evolving progress of the scenario. These simulations often change the ground rules or parameters throughout the exercise to constantly challenge the student's decision making ability. Another common approach is to simulate individual shop floor machines by computer "stand-ins" [5] often using proprietary simulation software such as Quest® by Deneb or Arena® by Rockwell Software Ltd.

In order to meet the requirements described above, within the constraints of large student numbers and less than optimum available contact time, the INFOstation concept was developed [6]. The concept was designed not to mimic the powerful layout/process simulation and 3D graphics abilities of proprietary software such as Arena® or Quest® or to have the student work through a single-issue simulation. Instead, INFOStation 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. For example, the INFOstation simulation has within it: Administration and Financial Departments and their associated systems as well as the more usual Design and Manufacturing Departments.

When fully developed, it is intended that INFOstation will consist of a number of multimedia based "modules," each of which will cover a specific 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 background resource information. As part of the evolutionary process of developing INFOstation, in 2002 a redesigned and more immersive "Ergonomics Project" was presented to students. This development is described in more detail later.

THE VIRTUAL COMPANY

In the third year of their engineering degree, students are first introduced to the concept of the virtual company in an assignment designed to reinforce and apply their knowledge of ergonomic principles to workplace design using the "virtual company" name of INFOstation Limited.

INFOstation Ltd. is the virtual manufacturing organisation that will be the basis of ongoing development. It is a medium sized manufacturing organisation, which has a virtual workforce of two hundred people, 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 intended that a live connection be made, via the Internet, with a real local manufacturer, as suggested by Dessouky and Verma [7].

INFOstation Ltd. has a web site on the School of Engineering's Intranet and its home page contains, background information about the company as well as links which connect the student "employee" to the web pages of other departments within the company which they may need to "visit" and/or obtain information from. Some of these are shown in Figure 1.

The company currently encompasses four departments - the Design Office, Planning Office, Quality Assurance Department and the Administration Office. Further developments will see the addition of several more functional areas to complete the enterprise.

ERGONOMICS PROJECT

One of the exercises which students are required to complete is an ergonomics assignment in which the students are told, through 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. They are also told that this responsibility includes ensuring that staff are not required to carry out tasks which may be dangerous, stressful, 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 requirements.

After joining the Planning Department as an "employee," the student receives a memorandum from their "employer," the Manufacturing Manager, asking them to complete an ergonomic investigation into a handling operation that is causing some concern to both the employees and their trade union representative.

The project scenario is based on a real process from industry where an operator performs a sequence of repetitive tasks. The job consists of the operator removing packs of empty drink cans from a pallet, placing them on a conveyor and unbundling them ready for filling. The total job cycle included removing the packs from a six layer high stack on a pallet so that reaching from eye height to almost floor level was involved. Since the packs were three deep across the pallet, the task also involved different severities of horizontal reach. The analysis of the task covered the unstacking of the complete pallet load which enabled an investigation into the total severity of the job to be established. For the assignment, however, the students were asked to analyse only the most severe motions for the operator during the work cycle.

The objectives of the exercise were to:

- Make students aware of ergonomic issues in the workplace.
- Reinforce and extend the material covered in lectures.
- Obtain some hands-on experience in industrial problem solving and productivity improvement.
- Give students practice in learning and working with professional computer-based analysis tools.
- Practice the professional skills of communication and report writing.

Students accessed a short video clip of the operation on-line (Figure 2) as well as some data collected by earlier investigators from the web sites of the appropriate departments within the organisation. This data included the length of a work shift, the body weight of the operator, the weight of the load handled and industry work practice standards.

Students used a commercially available software package called ErgoEASE,© which they accessed from the Planning Office, to perform the ergonomic analysis. The program, uses a graphical interface which allows students to input the results of a detailed methods analysis together with general task parameters, and produces a range of reports on the ergonomic impact of the operation. The program has a number of detailed graphical help screens to assist students who are unfamiliar with the terminology and acronyms used in the field of ergonomics.

PROJECT FORMAT

In the assignment, students were sent a memorandum indicating that a detailed ergonomic analysis of the job was required and that they should submit a report to the manufacturing manager on completion of their study.

It was indicated that their report should include among other things:

- a). Analysis of the employees energy expenditure in performing the task.
- b). Comments on the ergonomic impact of the total job of unloading the pallet.
- c). A complete Rapid Upper Limb Assessment (RULA) analysis on what they regarded as the most ergonomically sensitive parts of the work cycle.
- d). Recommendations on a suitable illumination level for the workspace based on relevant industry standards.

It was suggested to students that, as a competent INFOstation employee, their solution should consider all the usual relevant commercial issues and constraints, such as; cost of implementing any changes recommended, the anticipated effectiveness of their solution, pay-back period, downtime, likelihood of staff/union acceptance and compliance with health and safety requirements.

STUDENT FEEDBACK

The results from an anonymous feedback survey completed by the participating students was collected and analyzed at the end of the project. The questionnaire covered responses to both the specific ergonomics project and the overall virtual company approach to learning. The questionnaire made ten specific statements, covering both aspects, and the students responded in one of six ways. The percentage responses to the statements are shown in Table 1. In addition to responding to the statements by circling one of the six options available to them, students were also encouraged to complete an open-ended section which solicited their comments.

Overall, the responses were very encouraging and indicated a general acceptance of both the virtual company concept and the realistic nature of the project assigned to them. The feedback also indicated that there were some significant pedagogical issues raised within the exercise itself. Some students had difficulty in understanding what was required of them. This appeared to be because they were not used to receiving instructions, or data, in a narrative form, in this case in the format of a typical company inter-departmental memorandum. Another problem concerned the use of the ErgoEASE software itself. Although not difficult to use, students had little time to become totally familiar with it. As a consequence, some students attempted to use all of the program's analysis modules when only one was required for the purpose of the project. This led to some students producing analyses which were not required by the memorandum of instructions.

In general, however, students felt that the INFOstation format made the ergonomics assignment more interesting and lifelike. The particular students who were personally interviewed following the exercise, indicated that they were keen to have other topics delivered in a similar manner.

PROPOSED FUTURE DEVELOPMENTS

In the first semester of 2003, the 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 for the organisation. 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, take notes of important parameters and use the data to produce a report containing a recommendation for purchase and an analysis of the expected return on investment. This exercise will be a part of a general Engineering Management course in which Manufacturing Systems students participate.

Year four students involved in a Design course in 2003, will also use INFOstation to participate in a "design for assembly" exercise in which they will access a knowledge based expert system from INFOstation's Design Office. This will assist them in carrying out re-engineering analyses on a range of products. In late 2003 and 2004 the concept will be extended further to include topics such as design for "x," quality assurance, resource utilisation and environmental issues.

To support the development of the INFOstation initiative, research will also be carried out into producing an assessment instrument to gauge the reliably and effectiveness of the overall concept and of individual modules within it. There is a need to discover which topics and assessment techniques are most suitable for this "virtual company" approach.

CONCLUSIONS

The staff involved in the development of the INFOstation concept and its application in the teaching of specific topics to engineering students believe that the ergonomics exercise was successful. By delivering the topic in a more immersive fashion students felt that it was more "realistic" and more interesting than "run of the mill" assignments. The completed reports were generally of a high quality with some students really entering 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 technical report.

This project, like all new course design initiatives, requires 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.

From the feedback gained, it would appear that students learned a significant amount about extracting data and instructions from a typical industry memorandum. This area will also 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 for whom English is a second language. There is a desire among academic staff to investigate this area of narrative scene-setting to discover if there is a saturation point where information overload becomes a problem and students loose sight of the task on hand.

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FIGURE. 1
VIRTUAL COMPANY'S HOME AND DEPARMENTS PAGE S ON THE INTRANET

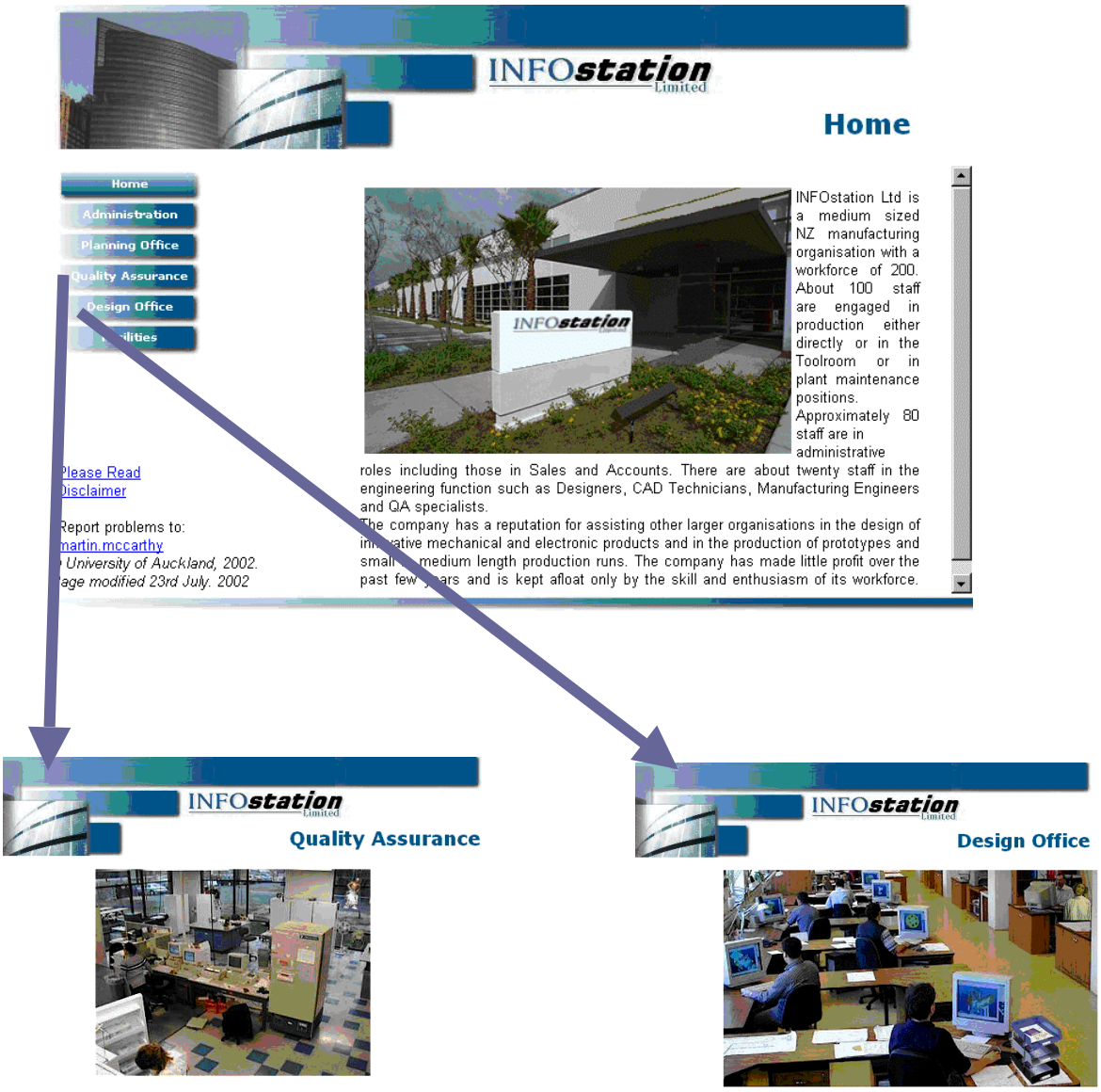

FIGURE. 2
A VIDEO FRAME FROM THE ERGONOMICS PROJECT

TABLE 1
PERCENTAGE RESPONSES TO STUDENT FEEDBACK SURVEY

Key:- SA - Strongly Agree
A - Agree
U - Undecided
D - Disagree
SD – Strongly Disagree

SA	A	U	D	SD
The INFOstation web pages were clear and uncluttered				
14%	74%	10%	2%	0%
The number of hyperlinks per page was about right				
8%	60%	24%	8%	0%
The hyperlinks on the web pages are clearly identifiable				
10%	54%	23%	13%	0%
Important data on the ErgoEASE© project was easy to find				
4%	56%	28%	12%	0%
Navigating my way around the INFOstation site was easy				
24%	54%	16%	4%	2%
The instructions in the manager's memo were easy to interpret				
13%	55%	21%	9%	2%
I could obtain all the information needed to complete the project				
10%	52%	24%	6%	8%
The use of a real industry scenario added interest to the project				
20%	48%	24%	2%	6%
The use of an industry scenario added relevancy to the project				
13%	52%	23%	10%	2%
I would recommend that this concept be extended to other topics				
14%	64%	20%	2%	0%