Further Developments in Multi-Media Immersive Teaching for Students of Manufacturing Systems

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Abstract: *This paper discusses the development of an immersive approach to teaching engineering students at the University of Auckland in the fields of Manufacturing Systems and Engineering Management. Project based learning initiatives in the Department of Mechanical Engineering have met with success and the Manufacturing Systems Group within the Department has continued with the development of its INFOstation virtual factory concept launched in 2001 and described by Seidel (2001). In 2002 and 2003 the concept has been expanded to include an immersive ergonomics project and a simulated capital equipment purchase exercise for students studying management accounting as part of a professional development course. This paper describes these initiatives, presents the results of student feedback on the ergonomics project and discusses what must be done to expand the INFOstation concept further in 2004.*

Keywords: *learning technologies, immersive learning, manufacturing systems*

The engineering degree at Auckland University

The University of Auckland offers a four-year Mechanical Engineering undergraduate degree. Year Three of the degree contains a compulsory course in Manufacturing Systems, which consists of an introduction to a broad range of manufacturing topics. The material covered ranges from product design and manufacture to industrial engineering techniques, ergonomics, automation principles, CAD/CAM, Robotics and factory/workstation planning. Students considering a career in manufacturing operations or manufacturing management will also take an elective Technology Management course in Year Four. This course reinforces their earlier year's work by requiring them to investigate, analyse and suggest solutions to real and current industrial manufacturing problems at local companies. With only two specialist manufacturing systems courses in the degree programme it is 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

particular it is difficult to emphasise and demonstrate to students the importance of systems integration and timeliness in the manufacturing sector as described by McCarthy (1996).

Project based learning

In order to give students an appreciation of actual manufacturing systems and processes and to maximise their workplace experience the Manufacturing Systems Group in the Department of Mechanical Engineering has for several years placed emphasis on a project based learning approach proposed by Tedford (1998). Year Four students (in groups of three or four) are, 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. This is an effort to get away from assignments and laboratory experiments being carried out by just mechanically following given instructions. To successfully complete the course, students must demonstrate initiative, planning and teamwork and be prepared, if necessary, to carry out work and organise meetings outside what would normally be considered to be their `working hours'.

This emphasis on project-based learning whilst an improvement on solely lecture based education, cannot deal with all the problems associated with maximising manufacturing systems learning experiences for students. Although students discuss their allocated project with managers and others in the host company and learn about organisational structure, communication, note taking, etc., they are often not exposed to, or do not have time to explore, the full range of activities in the organisation and appreciate fully the complex interaction of job functions and processes in the plant. Generally speaking the complexities and interlocking operations of a typical manufacturing company are not fully experienced or understood.

As a means of extending the students manufacturing systems experience without utilising further visits to local companies, which are resource and time intensive, the Manufacturing Systems Group developed the INFOstation concept. INFOstation consists of a number of hypertext and multimedia based modules each of which covers a different aspect of manufacturing.

A brief description of INFOstation Limited

INFOstation Limited is a virtual manufacturing organisation that exists in the form of linked web pages on the Department's web server accessible to all students and whose initial concept was described by Seidel and Sitha (1999). The design scenario is that of a medium-sized manufacturing organisation with a virtual workforce of 200 spread across manufacturing, design and administrative functions. The INFOstation Limited homepage is shown in Figure 1.

Figure 1: The INFOstation Home Page

The ergonomics assignment

To trial the use of the virtual factory concept (as a replacement for local company visits to observe ergonomics issues in the workplace) an ergonomics assignment was delivered to the students using INFOstation Limited in 2001. This project was designed to make students aware of ergonomic issues, to reinforce the material on ergonomics covered in lectures, give students further practice in getting to grips quickly with professional engineering software (ErgoEASE®) and to practice the important skills of professional communication and report writing. In 2002 the assignment was refined and adapted as a result of student feedback. The refinements included modifying the multimedia interface to improve speed and realism and being more explicit as to what data was required in the students' final report.

To commence the assignment, students log onto the INFOstation Home page. Anyone may access the INFOstation web site, however, access to the ergonomics software is limited by the IS supervisor to students enrolled on the Manufacturing Systems course. Once logged in students are instructed that the company's ‘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 the staff are not required to carry out tasks that may be dangerous, excessively tiring, or detrimental to their health.

To make the assignment replicate a typical workplace project as closely as possible the students were asked to review an e-mail from the Manufacturing Manager at INFOstation asking them to immediately complete an ergonomic investigation into a handling operation that was causing concern. The e-mailed memorandum from the INFOstation Manufacturing Manager is reproduced below.

"Please complete an ergonomic investigation into our can 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. I would like you to 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 to me I would like you to:
a). Calculate the Maximum Kilo Calorie Rate/Minute (from your ErgoEASE® results).
b). Comment on the ergonomic relevance of the particular lifting cycle you have analysed in the context of the total task of unloading the pallet.
c). Complete a Rapid Upper Limb Assessment (RULA) analysis on what you regard as the two most ergonomically sensitive parts of the cycle.
d). Recommend a suitable illumination level for the workspace".

Having received the e-mailed instructions outlining what was required in their report and some basic workstation parameters, students clicking on a videocassette icon viewed a video clip of the operation (Figure 2) and some data collected by an earlier employee investigator. This data included the length of a worker's shift, the body weight of the operator concerned and the weight of the load being handled.

Figure 2: A still from the ergonomics video

The handling operation consisted of an operator removing bundled packs of 30 cans from a pallet, transporting them to a conveyor bench, unbundling the cans and pushing them onto a conveyor. The pallets were stacked six high forcing the operator into overhead reaches and, at the bottom of the stack, a severe crouching position. The operation also involved an extended horizontal reach to grasp the bundles in the middle of a pallet. The students could replay the video as often as they required and were able to step through the video in single frames in order to analyse accurately the various motion elements involved. A professional software package called ErgoEASE® was used to perform the ergonomic analysis. This program accepts input of each of the motion elements in the task (stepping, grasping, pulling, lifting, etc.) and produces a report on the ergonomic safety of the operation, amount of energy expended, etc.

It was suggested to students that as competent INFOstation employees their 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, etc.

Student response to the INFOstation ergonomics assignment

Following completion of the ergonomics assignment in 2002 students were surveyed to discover what they felt about the use of the INFOstation immersive scenario and whether or not they felt that it was an improvement to more conventional delivery systems. The survey instrument was developed in conjunction with the University's Centre for Professional Development and consisted of eight questions. Four of the questions were concerned with the design of the INFOstation interface whilst the additional questions (See Figure 3) dealt more broadly with the virtual factory concept and whether or not it should be extended to assist in the delivery of other topics. Students were asked to indicate their opinion on a five-point scale from "strongly agree" through to "strongly disagree". The survey was designed to give staff a reasonable level of feedback on the INFOstation concept whilst at the same time being quick and easy for the students to complete.

The results from this survey were encouraging. There was a substantial majority of students who agreed, or strongly agreed, that the INFOstation scenario had added interest and relevance to the project and indicated that they would like to see the concept extended. In future surveys it would be of interest to investigate to what extent, if any, a student's learning style preferences and personality type pre-dispose him or her to support this method of presentation.

The following Figure 3 lists the four 'broad issue' questions asked together with the student's responses.

Question	Strongly Agree (%)	Agree (%)	Undecided (%)	Disagree (%)	Strongly Disagree (%)
I had, or could obtain, all the resources I 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	12	54	22	10	2
I would recommend that the concept of industry based scenarios be extended to other Manufacturing Systems topics	14	64	20	2	0

Figure 3: Table of survey results

It can be seen from the table above that 24% of students were undecided about whether or not they had, or could obtain, all the resources needed to complete the project. The next survey of this course will attempt to elicit more information about students' attitudes/concerns in this area.

Discussions with students during the course of the assignment and at its completion were positive. Students felt pleased that they had met the challenge of quickly learning and producing results from a new software suite in an area new to them. Many comments were received about the use of the video clip of a real workplace manual task and students expressed empathy/sympathy with the hard-working operator in the video and although they had never met her several students remarked that at the end of the exercise they felt they knew her well.

Latest developments

Encouraged by the success of the ergonomics project the INFOstation concept will be expanded in the first semester of 2003 by opening further pages on the INFOstation web site

describing the activities of INFOstation 's administration and accounting functions. To involve the students in this part of the organisation's activities it needed to be introduced during the Year Three Professional Development course which is dedicated to studying 'Engineering Management' tools and strategies. The new INFOstation activity is focussed on the topic of Management Accounting, a substantial proportion of the course (33%).

Management accounting assignment

The previous management accounting teaching material consisted of a series of notes on issues such as balance sheets (financial statements), rate of return, opportunity costs etc. with the notes being supplemented with a number of worked examples. The examples, however, were a mixed bag of imaginary organisations from "Sid's Barbershop" through to the "All-Day Candy Company". This disparate collection is now being replaced by examples more closely related to engineering and with INFOstation Limited as the common theme.

The management accounting assignment that students must complete in this Professional Development course has also been redesigned to make use of the INFOstation Limited concept. The manufacturing manager of INFOstation presents the students with the problem of a lower than expected throughput of a manufacturing process. Students are required to analyse their options for improvement including the selection and purchase of one or more computerised automated assembly machines. Students must compare the capital costs, installation and maintenance expenses and expected payback period of each alternative. They must allow for the costs of borrowing, depreciation and expected return on investment. The assignment is designed to give students practice in applying what they have learnt during the management accounting lectures and an appreciation of the decisions that must be made when a company is considering reinvestment in plant. It is also designed to equip them with the tools to adequately argue a financial case to colleagues and managers.

The participants in this course, as engineering students, are not always convinced about the relevance of management accounting to their chosen profession. It is hoped that the INFOstation context within which this topic is delivered and the consistent theme will help to demonstrate to students the relevance and importance of this area to practising engineers. Almost all graduates of course will at one time or another share responsibility for earning, allocating, and spending their organisations liquid assets.

Design Projects

In addition to the delivery of the ergonomics and management accounting material described above, the INFOstation concept has been used in 2002 and 2003 to deliver design problems to Year One and Year Three students in a design course in as immersive a fashion as possible at this stage of development.

Design projects are based around a customer inquiry presented to the students in a letter by the General Manager of INFOstation Limited. The letter is addressed to 'Engineering Design Consultants', a fictitious commercial design consultancy consisting of the different project groups established in the class. The project task is based on a relatively vaguely defined design problem that the project groups first have to process systematically through the needs assessment phase into a formal product design specification. In the next project phase they have to apply a structured approach and a number of creative techniques and decision making tools to create a range of concept ideas, select one of these alternatives and then to develop this into a comprehensive conceptual design proposal which they present as a written design report.

Further development

Our experience with the benefits of the INFOstation concept have encouraged us to continue with its development and refinement. At this stage it seems near to reaching its full potential as a vehicle for the delivery of immersive student assignments and projects. If it is to be truly a virtual factory around which the teaching of manufacturing systems at the University is to revolve, it will now need to be incorporated fully into relevant lecturing and tutorial materials used in the department. In particular it is envisaged to create a link between the virtual INFOstation environment and the manufacturing hardware facilities in the Department's laboratories.

Currently the laboratory for the Manufacturing Systems Research Group includes an industrial KUKA robot (payload 15kg) and a smaller Eshed robot (payload 1kg), a computer numerically controlled lathe, a milling machine, conveyor system and a number of pneumatic control tool kits. The laboratory also has a number of software tools including Pro/Engineer for computer aided design, manufacturing and engineering; Quest a manufacturing simulation tool; EASE for industrial engineering optimisation and ErgoEASE, an ergonomic analysis tool.

Currently the Cell is used to assist students with investigations into robotic programming, robotic assembly and CNC programming. The planned link between the INFOstation and the cell will give students some exposure to workplace integration problems, procedures and software. The union of the existing hardware and software tools with INFOstation will enable us to expand INFOstation into the simulation of manufacturing system functions such as statistical quality control methods, cycle time analysis, material and machine hour costings, reliability analysis and scheduling issues. All of these functions have the capability of expanding and enriching the immersive experience for students. In future developments it is possible that a live connection could be made via the Internet with a local manufacturer as suggested by Dessouky and Verma (2001).

When these steps have been taken INFOstation's useful new function would be to act as an integrating agent to assist staff to demonstrate the holistic nature of engineering activities. Industry now recognises the fact that marketing, quality, engineering, manufacturing and production can no longer operate independently and has created new approaches to product design and manufacturing such as concurrent engineering and integrated product development. INFOstation's next evolution will be to demonstrate the reality of integration and act as the common link in teaching product design, design for production and assembly, materials and process selection, and assessment of a product's financial viability.

This next step in the evolution of INFOstation will require its developers to win the 'hearts and minds' of their colleagues to assure them that the time and energy they will need to expend to incorporate the INFOstation concept into their exiting teaching practices and material will pay handsome dividends. Rather than being a drawback the authors of this paper believe that this challenge will help to refine and optimise the concept and help them to ensure that each incremental concept development is backed up by demonstrable pedagogical benefits along with approval from students.

Conclusions

The staff involved in the INFOstation project and its application to the teaching of design and ergonomics issues to engineering students believe that the exercises were successful and this is strongly borne out by the results of the survey carried out after the completion of the ergonomics assignment. 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 returned assignments were generally of a high quality with some students really getting into the spirit of the exercise and presenting their results and commentary in the format, style and language they would be expected to use in a workplace memorandum and technical report. Students learnt a great deal about extracting data and instructions from a wordy memorandum. A survey will be carried out at the completion of the Professional Development course to see if these benefits were also observed by the students involved in the management accounting assignment.

The next and perhaps most challenging step, is to introduce an immersive and consistent virtual factory scenario to general teaching and tutorial material. This will require the co-operation of a wider range of teaching staff than have been involved to date and require those involved in the ongoing development of the INFOstation project to be thorough in their development plans and pedagogical justification for its use.

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