Enhancing student engagement in manufacturing engineering courses

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ABSTRACT: In this article, the authors attempt to overcome the problems of limitations in time and resources, and they investigate the use of multimedia and computer technology for the delivery of complex non-quantitative topics in undergraduate manufacturing courses. The authors also discuss the application of these technologies and evaluate their effects on student learning. The ongoing research described in the article is motivated by a desire to improve student engagement, enthusiasm and capability in undergraduate manufacturing engineering courses, and to assist students in perceiving the topics covered as being coherent and integrated bodies of knowledge, thus reinforcing the *Conceive – Design – Implement – Operate* (CDIO) concept of integrated and active participative learning. Research results collected from direct observation, questionnaires, interviews and student journals are evaluated to determine whether enhanced learning outcomes were achieved by the techniques used and to what extent they complement the CDIO concepts.

INTRODUCTION

There are two primary motivational factors behind the development of the virtual teaching organisation described in this article. The first is a desire to contribute to the ongoing research effort to develop coherent pedagogical theory and practice for the effective application of multimedia technology in engineering education. In particular, the authors investigate multimedia applications to courses in complex, non-quantitative topic areas, such as the organisation of manufacturing systems and manufacturing management. The second motivator is the wish to confront three ongoing problems, described below, in the delivery of courses covering these topics.

Insufficient Contact Hours with Students

Contact hours with students in manufacturing courses are restricted, as indeed they are in many other courses. Often, academic staff find it difficult to adequately expose students to what is considered to be core professional knowledge for future engineering managers and manufacturing engineers, and to ensure that students obtain clear and cohesive views of these topics [1]. This issue is aggravated by the increasing size of classes in these courses. Contact with students in tutorial sessions is also limited. In many cases, tutorial groups are so large that detailed *one-on-one* discussion, or an explanation of issues students might not be clear about, is not possible.

Welding the Topics into a Contiguous Whole

Students have trouble viewing the topics taught in the *Manufacturing Systems* course as a coherent whole. In many cases, the material covered in an earlier *Management for Engineers* course does not appear to be carried over cognitively and be used, as intended, as core underpinning material for their studies in a following, second semester, course *Manufacturing Systems*. An aggravating factor in this may be the fact that, unavoidably, many topics in both courses are presented by different lecturers.

Appreciating the Importance of *Integration*

Systems integration is the key to the operation of successful and profitable manufacturing organisations. An efficient manufacturing environment integrates a wide range of physical resources from standalone and continuous flow machines through to raw materials, labour allocation and shop floor computing networks. Less tangible systems, such as management planning and quality systems, also have to be seamlessly fitted into the operation. In manufacturing industries, the processes of product design, systems/project control, as well as the management of manufacturing operations and equipment, are interactive, dynamic and interrelated. Unlike certain topics, such as mechanics, thermodynamics or control systems, this issue of systems integration is difficult to demonstrate, explore or manipulate in conventional lecture or laboratory sessions.

A project-based learning approach has been described by Jensen et al to deal with these problems [2]. It has been utilised at the University of Auckland in Auckland, New Zealand, with encouraging results from both Seidel and Tedford [3][4]. However, this approach does not generally solve all of the problems associated with providing the best possible learning experiences for students. Students are generally not exposed to the full range of activities within the organisation. As explained by both McCarthy and Dessouky, the complexities and integrated operations of a typical manufacturing company are, in general, not understood [5][6].

As educators, we have to develop a teaching methodology that gives students an understanding of how each sub-process or system combines with others to form a functional manufacturing organisation. It is hoped that the virtual organisation described in this article will assist in promoting this understanding. The authors' aim is to present a complex, primarily non-quantitative, topic, such as manufacturing systems, in a manner that will assist in overcoming the problems listed above and increase the levels of student engagement and enthusiasm.

One learning theory model that seems to have particular applicability to this context is Perry's model of intellectual development [7]. In applying this model to this project, the authors have endeavoured to set students tasks that will increase their levels of intellectual development by presenting problems that are *fuzzy* and which take students out of what one might call their *comfort zone*.

Briefly, Perry's model is that maturing students move intellectually from a black and white, dualistic (right versus wrong) view of the world, to one that allows for uncertainty and shades of grey; a relativistic view. The importance of this model for engineering educators is that it posits that students will not be able to understand or answer open-ended problems that require a stage of intellectual development beyond that which they currently possess.

The virtual company described in this article is an attempt to improve students' ability to solve open-ended problems, make judgements, use evidence and evaluate alternatives utilising Perry's model as a viewpoint from which to evaluate their progress. The virtual company presents students with realistic, problems drawn from life that have vague or fuzzy data sets and ambiguous required outcomes, and provide an introduction, perhaps a shock one, to real-life manufacturing engineering.

Bruner's cognitivist theory posits that learning is an active process in which learners construct new ideas or concepts based upon their current or existing knowledge [8][9]. To incorporate Bruner's concepts into the design of the virtual organisation, we should strive to ensure that students are encouraged to discover principles by themselves. Bruner states that instruction methods should present material in its most effective sequence and be structured in such a way so that it might be most easily understood by the learner.

This has been attempted in the virtual organisation described here by providing students with core theoretical information that is synchronised with the requirement for students to solve real problems and allied practical tasks. They follow, and are involved in, the design, implementation and growth of a manufacturing system from initial plant layout to the delivery of finished goods. By situating the course material within the context of a complex virtual manufacturing organisation, it is believed that students will see the relevance of the subject matter and the connectivity or integration between different topics in the field and that they will refer to their previous work to help with present tasks. For instance, they will need to review the results of an earlier process simulation exercise in order to complete their production scheduling assignment. It is believed that an increase in engagement and enthusiasm on the students' part will result in a greater willingness to carry out their own research to supplement the material supplied by the lecturing staff.

The Team Detectors project aims to assist students to gain a comprehensive understanding of the design, planning and manufacturing processes as complete and integrated entities by making Team Detectors Ltd the scenario within which a number of multi-topic student projects are presented.

The virtual company has a number of modules, each of which covers a different aspect of manufacturing. Each module provides students with the necessary parameters to analyse and solve an open-ended problem, as well as providing comprehensive resources on a particular aspect of manufacturing. An immersive ergonomics project has been successfully presented to students. The project is designed to provide students with a narrative that will give them alternative and possible solutions to an engineering manufacturing problem with conflicting, but viable, opinions offered by competent authorities and managers within the virtual organisation. There are no obvious links with the course lecturer who can thus take the stance of a neutral advisor. It is planned that, faced with these alternative *authoritative* opinions, students will be encouraged to abandon their positions of duality and adopt a more relativistic position in their analyses and recommendations for a *best* solution. It is envisaged that this will assist students to raise their level of intellectual development as measured by the Perry scale.

TEAM DETECTORS LTD

Team Detectors Ltd is the virtual manufacturing organisation that will be at the core of ongoing development of immersive teaching methods. The company has a Web site hosted by a commercial ISP in an effort to detach it from the university environment and increase the realism of the scenario.

The company is a medium-sized manufacturing organisation with a virtual workforce of 200 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 20 staff in the engineering function, which includes designers, manufacturing engineers and QA specialists. The company encompasses four units: the Design Office, Planning Office, Manufacturing and Administration (including Accounts Department, Marketing and Sales). The homepage for the organisation, as utilised in the facilities layout and simulation assignment, is shown in Figure 1.

FACILITIES LAYOUT AND SIMULATION ASSIGNMENT

The purpose of this assignment was to reinforce material taught in the *Manufacturing Systems* course on the topics of factory layout and process simulation. It was delivered via the virtual company in a manner that would, it was expected, promote a less dualistic and more relativistic mode of thinking and analysis by students.

Students received an instruction from Team Detectors Ltd to visit the company's Web site in order to learn the details of a proposed move to a new factory and to view a plan of the site and of the new, empty building. Also on the Web site was a report by the company's managers describing the departments that were to be relocated, their function, approximate floor area, and any co-location restraints between them. This report had some inconsistencies deliberately included so as to ensure that the co-location requirements could not be fully met without compromises.

In order to raise the *vagueness* factor a little, the positions of some departments on the site were implied by their function rather than being explicitly stated. For example, it was hoped that students would, without direction, place the Goods Inwards and Dispatch departments in such a way that they had frontage onto the access road and that the visitor reception area would be placed at the front of the site close to the main highway. Students were expected to use a formal methodology, such as Muther's Systematic Layout Planning (SLP) approach, to analyse and best meet the co-location requirements [10]. Demonstrations of Muther's SLP and other systematic methods of optimising facilities layout had been introduced to students in formal lectures.

Figure 1: Homepage of the virtual company.

For their submission, students had to draw the site and building in a plan, marking the boundaries and location of the departments within the building. They were also required to find the approximate geometric centre of each department as an aid to calculating product movement distances from department to department, which was needed for the next stage of the assignment.

The Team Detector's management also required students to simulate production flows within their planned new layout. Students were given details of a product, its manufacturing process and the departments it was processed in, the machinery and staffing available for production and a target production rate. In order to supply a report to the company, students had to simulate the plant layout, machine production rate, waiting times, queue lengths and inspection stations utilising the software package *Arena*® from Rockwell Software Inc. Travel times from department to department on an overhead conveyor were calculated utilising the centre-to-centre distance between departments as described earlier. Students had been introduced to simulation techniques and the use of the *Arena*® software in lectures and tutorials. Students needed to analyse production flows and discover if there were any production bottlenecks.

They were then to advise the company if the required production target could be met by their proposed layout with its equipment and staffing levels. If, in their opinion it could not, they were to make justified recommendations for changing key parameters, such as staffing levels, the number of shifts, equipment, etc, and to present this in the form of a professional business report.

ASSESSMENT OF THE TEACHING TOOL

It can be difficult to measure the benefits of multimedia and immersive teaching methods when applied to complex non-quantifiable topics like manufacturing systems and management. Existing traditional assessment methods, such as test and examination results, are probably not sufficient to be the only tools utilised in these circumstances. A decision has yet to be made on the most effective way of measuring success in this area. However, in order to examine the relationships between immersive, multimedia teaching and the overall resulting educational outcomes for students, a methodology has been selected that includes a broad range of assessment systems.

The methodology adopted to measure the ongoing cognitive results of utilising the virtual company, ie how well students understand and can apply the material covered, is *development research* [11][12]. This methodology is becoming increasingly popular with researchers in the areas of professional education, online teaching and the development of instructional technology.

Development research aims to improve educational practice through a systematic and flexible *design-implementation-review* cycle of practical, educational interventions and innovations in lectures and assignments. The programme leads to design principles or theories that can be applied more generally. The development research methodology is designed as a means of dealing with the complex environment that is typical of research in an educational setting.

A key characteristic of the methodology is the interactive nature of the process as conjectures are generated, and perhaps refuted, and new conjectures developed and subjected to testing. The result is an iterative design process of cycles of invention and revision. The outcome is a framework of theory that helps to describe the observed outcomes and can be used to specify the focus of investigation during the next cycle of inquiry to inform and improve practical teaching.

Development research will be utilised to support the continuing development of the narrative rich, multimedia method of course delivery of the Team Detectors virtual company and provide researchers with the empirical evidence for its effectiveness.

Figure 2 illustrates the differences in concepts between predictive research, as usually applied to *laboratory*-based research efforts, and development research. The latter can be used to support the development of a prototype multimedia method of course delivery and provide the empirical evidence for their effectiveness. It also assists in methodically evaluating the design and evaluation of such interventions.

PRELIMINARY RESULTS

Following the completion of the factory layout and process simulation assignment in semester 2, 2005, a randomly chosen sample of 12 students (from a class of 65) were interviewed in order to discover what they felt about the use of the Team Detector scenario.

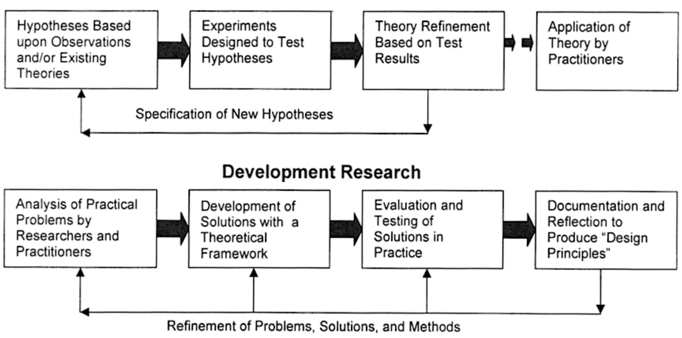

Figure 2: Alternative research concepts [12].

The interviews were designed to prompt the students to talk freely about the assignment and consider whether or not they thought the experience would make it easier to deal with any ill-defined and open-ended problems they might be confronted with in the future. They were also asked if they felt that the virtual organisation concept was worth continuing with for future courses. The results from the interviews were encouraging. Eight of the students felt that the assignment would help them with future *fuzzy* assignments with incomplete data and/or vague directions. The other four students were not sure if the experience would help them or not. The students were unable to say if the experience had prompted them to question the inevitable existence of a *right* answer to all problems, ie to a more relativistic stance. All but two of the students interviewed felt that the virtual company format should be continued.

At the completion of the semester, students completed a standard faculty-wide feedback form for the course. In this process, only three of the students commented specifically on the assignment. These students stated that the assignment was *vague* and, from one student, *It was confusing. I could only complete it by getting help from my friend.*

CONCLUSIONS

Informal feedback received from students while they were carrying out the factory layout assignment indicated that it was making them *think* about what they were engaged in, rather than simply *plugging numbers into a formula*. They also felt that they were being forced into making difficult decisions that involved choosing between two evils. Nevertheless, despite this apparent pressure to *think* about the problem globally, some students (25%) made basic errors, such as placing the visitor reception area at the rear of the site and the Dispatch Department in the middle of the building with no access to an outside wall or transport dock.

In general, the process simulation section of the assignment was completed well and students coped with learning the basics of *Arena*® with very little tuition time. The main problem faced by students was in making a decision as to how long to run the simulation in order to obtain meaningful results and what to do to eliminate any evident queues and bottlenecks. Students became aware of the fact that the better their earlier factory layout solution had been, the more efficient their production process would be, and that no-one was going to obtain the same *answer*. Students had been given little guidance as to what resources of money, staff or equipment could be called upon by Team Detectors in order to increase the production rate, should the simulation show it to be below target. Most students made a reasonable job of suggesting sensible changes despite this lack of information.

The next stage for the Manufacturing Systems Research Group is to continue the development of the methodology to be used to more formally measure the effects on student intellectual development triggered by this more immersive and narrative-based teaching approach.

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