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ENHANCING STUDENT ENGAGEMENT THROUGH THE APPLICATION OF MULTIMEDIA LEARNING THEORIES TO UNDERGRADUATE MANUFACTURING COURSES

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ABSTRACT

A problem associated with getting students to participate more fully in certain engineering courses, is the imposition, by many university administration's, on the availability of time and resources which can be expended within an undergraduate programme. In an attempt to overcome this problem, this paper investigates the use of multimedia and computer technology in the delivery of complex non-quantitative topics in undergraduate manufacturing courses. It also discusses the application of these technologies and evaluates their effects on student learning as well as reviewing the specific educational theories and strategies that underlie these concepts.

The ongoing research described in the paper 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 CDIO concept of integrated and active participative learning.

We describe the steps taken to confirm a theoretical basis for the development of immersive and narrative based manufacturing engineering education. We draw upon existing research and relevant literature which has been synthesized and filtered to select relevant and appropriate methodologies and pedagogical theories applicable to these issues.

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 paper. 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, to investigate multimedia application to courses in complex, primarily 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 in more detail below, in the delivery of courses covering these topics.

1) 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 at tutorial sessions is also limited. In many cases, tutorial groups are so large that detailed 'one-on-one' discussion, or explanation of issues students might not be clear about, is not possible.

2) 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.

3) 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 stand-alone 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, and the management of manufacturing operations and equipment are interactive, dynamic and interrelated.

Unlike 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.

Possible Solutions

A project-based learning approach has been described by Jensen [2, 3] to deal with these problems and has been utilised at the University of Auckland with encouraging results by Seidel [4] and Tedford [5]. This approach, however, 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 and as explained by McCarthy [6] and Dessouky, et al. [7] the complexities and integrated operations of a typical manufacturing company are, generally speaking, not understood.

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. The virtual organisation described in this paper, it is hoped, will assist in promoting this understanding. Our 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 levels of student engagement and enthusiasm.

APPLICABLE MODELS AND THEORIES OF LEARNING

In designing a multimedia virtual organisation for the delivery of manufacturing systems courses, we have attempted to ensure that the design can be validated against those theories of learning that we consider to have most applicability to this particular case. Currently, we are attempting to apply, primarily, the principles of Perry’s model of intellectual development and Bruner’s cognitive development theories.

Perry's Model of Intellectual Development

One model which seems to have particular applicability to us, is Perry’s model of intellectual development [8]. In applying this model to our project, we have endeavoured to set the students tasks which will increase their levels of intellectual development by presenting problems which are ‘fuzzy’ and which take the students out of what one might call ‘their comfort zone’.

William Perry, an educational researcher at Harvard University in the 1950s and 1960s developed a model of intellectual development which may be used by engineering educators to assist in the education of the many students who have difficulty in dealing satisfactorily with open-ended problems. His model suggests to us some teaching methodologies that may be adopted to assist students to overcome their inability to recognise that there might be more than one solution to a problem, or perhaps, not even a satisfactory solution at all.

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 which 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 which require a stage of intellectual development beyond that which they currently possess.

Perry's model has been explored and utilised widely in education but it has not been quite so influential in the engineering field. However, a number of researchers have worked on the application and development of the model in engineering including Culver, Hackos, and Fitch [9]. Later studies have generally confirmed the results obtained by Perry in his Harvard investigation [10].

Perry's model reinforces the conclusion of many theories of learning which is that, individual students have different preferences (and do best in) differing learning environments. Importantly, for the teacher who must mentor students through material and assignments of an open-ended or 'vague' nature, Perry's research indicates that students will not comprehend, or be able to handle without frustration, problems not matching their current level of intellectual development.

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

The Constructivist Theory of Learning

It seems to us that applying a constructivist approach to learning in the design of the virtual organisation would suit the sometimes subjective nature of the topics covered when studying manufacturing systems. This approach would also best match the open-ended problems and non-routine decisions to be made by students solving problems in manufacturing systems.

To define this approach briefly, constructivist learning theory maintains that the student constructs his or her own meaning by being an active participant and explorer in their environment. Any new information or any inconsistency between their existing knowledge base and a current new experience, is added to their existing knowledge base and modifies this knowledge in the light of the inconsistency discovered. This approach was succinctly defined by John Dewey, although not described as a constructivist himself, when he maintained that "Education is not an affair of ‘telling’ and being told, but an active construction process"[11].

Furthermore, it is suggested (and this is sometimes difficult to accept by those in the fact centred engineering and science fields) each person forms their own mental map of knowledge and therefore, there is no one single, correct representation of knowledge.

Adopting constructivist theory as a primary, but not exclusive, guide for the design of our virtual factory requires that our design will need to provide students with self-directed and multiple activities. A further factor to consider in the development of the design, is the constructivist viewpoint that learning tasks should be as relevant and interesting as possible, and should have some personal relevance for the students

Also important in this attempt to improve the teaching of manufacturing systems and management, is the work of Vygotsky. Vygotsky suggests that learning can only occur in interaction with others [12]. Students learn from their peers rather then just through their teacher. Although the existing virtual organisation and its associated assignments are designed with group work in mind, more work needs to be done by us in this area to ensure that we are exploiting this characteristic of learning effectively.

Cognitivism

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. To incorporate Bruner’s concepts into the design of our virtual organisation we should strive to ensure that we encourage students to discover principles by themselves. Bruner states that our instruction methods, should present material in its most effective sequence, and structure it in such a way that it might be most easily understood by the learner.

We have attempted to do this in our virtual organisation by providing students with core theoretical information 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, we believe 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. We believe that an increase in engagement and enthusiasm on the part of the students will result in a greater willingness to carry out their own research to supplement the material supplied by the lecturing staff.

With these strategies we believe that we can make some progress in applying the cognitive principles of Bruner’s theories as described by Kearsley (1994) in the following statements:

1. The context within which the material is presented must make the student willing and able to learn.
2. Any material should be presented so that it may be readily understood by the student by referring to previous material covered. This is a spiral organisation where old material is revisited and kept in view but from a different, *higher* perspective.
3. The learning material presented should be designed to enable students to fill in the gaps in their knowledge themselves by researching or interpolating beyond the information given.

In his classic volume ‘The Process of Education’ [13] Bruner states that the “teaching and learning of structure, rather than simply the mastery of facts and techniques, is at the centre of the classic problem of (knowledge) transfer. If earlier learning is to render later learning easier, it must do so by providing a general picture in terms of which, the relations between things encountered earlier and later are made as clear as possible”, and “a curriculum, as it develops, should revisit basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them”. This emphasis on ensuring that the particular structural relationships which are inherent within a domain (in our case, manufacturing engineering) are made clear to the student, has clear relevance to the problem described at the beginning of this paper – that of knitting together what students report is seen by them as a discontinuous series of isolated topics. The extract also refers to the importance of revisiting concepts to assist in knowledge reinforcement and in grasping the ‘whole picture’.

In the same volume Bruner writes: “Interest in the material to be learned is the best stimulus to learning, rather than such external goals as grades or later competitive advantage”.

“To instruct someone... is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce… living libraries on that subject, but rather to get a student to think… for himself. Knowing is a process not a product" [14].

Narrative

Narrative will be an important element in the presentation of this virtual organisation. As Margaret Bearman [15] points out there is an increasing interest in narrative in the pedagogical literature, if not amongst engineering educators, and she quotes Schank and Abelson [16] who maintain that stories form the basis of almost all knowledge, memory and comprehension. Bruner believes that narratives are vital for humans to make meaning of themselves and their cultures. He argues that in education the sciences have severely neglected this issue and it seems likely that the same criticism can be levelled at engineering.

Bearman [15] and Graesser [17] have published empirical studies clearly showing the vital role that narrative plays in the comprehension, recall and organisation of events. This area also needs more research by us to ensure that we are using narrative to its full potential.

Bruner [18] also insists that the narrative mode of thinking and organising knowledge must become a more integral part of education. While the narrative approach has always played a key role in the teaching of literature, history, and other interpretive subjects, it can also be useful in science education. He says, that the theories of science are fundamentally story-like, in the sense that they rely on metaphors, interpretive frameworks, and epistemological assumptions.

THE VIRTUAL FACTORY TEACHING TOOL

Bearing in mind the work of Perry in the development of intellectual skills, Bruner and his principles of cognitive development and Bearman and her work on narrative, a virtual manufacturing organisation (Team Detectors Limited) has been developed. 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 Team Detectors Ltd. concept was designed to provide a wide-ranging virtual scenario, which would concentrate on emphasising the interconnectivity of many tasks and processes within a manufacturing organisation. Thus, for example, the Team Detectors simulation has within it, administrative and financial departments and their associated systems, as well as design and manufacturing functions.

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 will be 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 the students using an earlier version of the concept in 2004 [6].

The project is designed to provide students with a narrative which will give them alternative, 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. This, it is believed, will assist students to raise their level of intellectual development as measured by the Perry scale.

Details of Team Detectors Ltd

Team Detectors Ltd. is the virtual manufacturing organisation that will be 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 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. The company encompasses four units - the Design Office, Planning Office, Manufacturing and Administration (including Accounts Department, Marketing and Sales). The Home Page for the organisation, as it was used in the facilities layout & simulation assignment, is shown in Figure 1 below.

Figure 1: Home page of the virtual company

THE 'FACILITIES LAYOUT & 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 factory in a way which 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 to learn details of a proposed move to a new factory and to view a plan of the new site and of the new empty building. Also on the web site was a report by the company's managers describing the departments which were to be re-located, their function, approximate floor area, and any co-location restraints between them. This report had some inconsistencies deliberately included to ensure that the co-location requirements could not be met in total without compromises. 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 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. The students were expected to use a formal methodology such as Muther's Systematic Layout Planning (SLP) approach [19] to analyse and best meet the co-location requirements. Demonstrations of Muther's SLP and other systematic methods of optimising facilities layout had been introduced to the students in formal lectures.

For their submission, students had to draw the site and building in 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 for the next stage of the assignment.

The Process Simulation 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, the 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 Arena® software in lectures and tutorials. The 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 change to parameters such as staffing levels, number of shifts, equipment, etc.

Example Extracts

The following extracts are from the material presented to the students to set up the scenario for the assignment. The first (a), is from the introductory narrative presented to students and the second (b), outlines the tasks required of the student by the company. The third extract (c), is part of the data sheet describing the planned process flow for the product; a smoke detection device.

a) “You are asked to determine an efficient layout for the manufacturing and other activities which will be accommodated in the area and to simulate some of these manufacturing operations based on an ARENA® model. The data from your simulation will be used to gain an estimate of the total time the main PCB for the smoke detection unit will spend in the system and to assess the likelihood of serious bottlenecks forming in the production process...”

b) “The chart attached (Activity Relationships) shows the estimated activity relationships between the activities and services that will be operating in the new area.
Using Muther's systematic layout planning procedure, draw a relationship diagram from this data and, using the details of the amount of space to be

assigned to each activity (see web page - http://www.teamdetectors.co.nz), draw a space relationship diagram and draw a completed departmental layout on the building plan…"

"Build an Arena® model of the manufacturing operations for the following four departments only: PCB Manufacture, PCB Assembly, Resin Encapsulation and Final Assembly…"

"Note: To calculate the inter-departmental transfer times, assume that the products moving between departments will be conveyed by a continuous loop overhead conveyor travelling at 5m/minute. The transfer 'delay' within your model should be set to your estimated transfer times on this conveyor. Assume that, on average, parts move on the conveyor from, and to, the departments' geometric centres as measured on your proposed departmental layout..."

c) "PCB Manufacturing Department: Cut-to-size and notched printed circuit board blanks will be produced by an outside supplier (outside the bounds of this model) and, as a result of using a planned just-in-time supply strategy, we expect to have batches of four PCB blanks arriving into the PCB Manufacturing Department every 40 minutes. Upon arrival they will be transferred, singly, to the PCB Etching and Drilling Machine. The process time on this machine is expected to have a minimum value of 5 minutes a maximum of 12 and a most likely time of 8 minutes. Parts leaving this operation will be transferred to the Lacquer Applicator & Drying Oven with a constant 20 minutes process time. On leaving this machine, parts will move to an inspection station where the time taken to complete inspection will probably have a minimum time of 6 minutes a maximum of 15 and a most likely inspection time of 9 minutes. It is expected that 95% of printed circuit boards will pass inspection. Parts failing inspection will be scrapped. Parts which pass will be routed to the PCB Assembly Department …"

The Ergonomics Assignment

A version of the virtual organisation has previously been used to present a multi-media ergonomics project [20]. The project scenario consisted of a real process from industry where an operator performs a sequence of repetitive operations. In this process, the operator removes packs of empty 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 high 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. 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 and 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 Team Detectors' virtual Planning Office, some ancillary data and a video clip of the operation (Figure 2) prepared by a "virtual" colleague. This data included the length of a shift, the body weight of the operator concerned and the weight of the load being handled.

Figure 2: A Frame from the Video

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 and produce a range of reports on the ergonomic safety of the operation, the energy expended, etc. The abridged 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 and 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.*

It was suggested to students that, as a competent Team Detectors 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.

ASSESSMENT OF THE VIRTUAL FACTORY TEACHING TOOL

It can be difficult to measure the benefits of multimedia and immersive teaching methods when applied to complex non-quantifiable topics such as manufacturing systems and management. Existing traditional assessment methods such as test and examination results are probably not sufficient to be the only tools used in these circumstances.

With regard to Perry's model of student intellectual development, it is generally agreed that individual student interviews of approximately one-hour duration are the most reliable way to measure any change in an individual's position. Unfortunately this technique is difficult, time-consuming and expensive, and requires experts in this field to carry out the interview and evaluate the responses.

There are several test instruments available which utilise pencil-and-paper methods including the Lee Watson Glazier Critical Thinking Appraisal [22], the California Critical Thinking Skills Test [23] and the Measure of Epistemological Reflection (MEP) [24]. This latter method requires students to write essays on topics derived from those utilised in the interview method with the essays again being rated by experts. The Learning Environment Preferences (LEP) questionnaire is an instrument utilising a Likert-scale [25]. These pencil-and-paper tests, especially the latter, are relatively inexpensive and easy to administer. Unfortunately they give ratings which are typically one or two intellectual positions lower than those that might be estimated by an expert analyser following a comprehensive interview. They correlate only moderately with the more accurate and consistent interview methods.

We have yet to make a decision on the most effective way of measuring our success in this area. However, to examine the relationships between immersive, multi-media teaching and the overall resulting educational outcomes for students, we have selected a methodology which will include a broader range of assessment systems.

The methodology adopted to measure the ongoing cognitive results of utilising the virtual factory, that is how well students understand and can apply the material covered, is Development Research [26, 27]. 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 which 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 helping 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 used to support the continuing development in 2006 of the narrative rich, multimedia method of course delivery of the Team Detectors virtual factory and provide researchers with empirical evidence for its effectiveness.

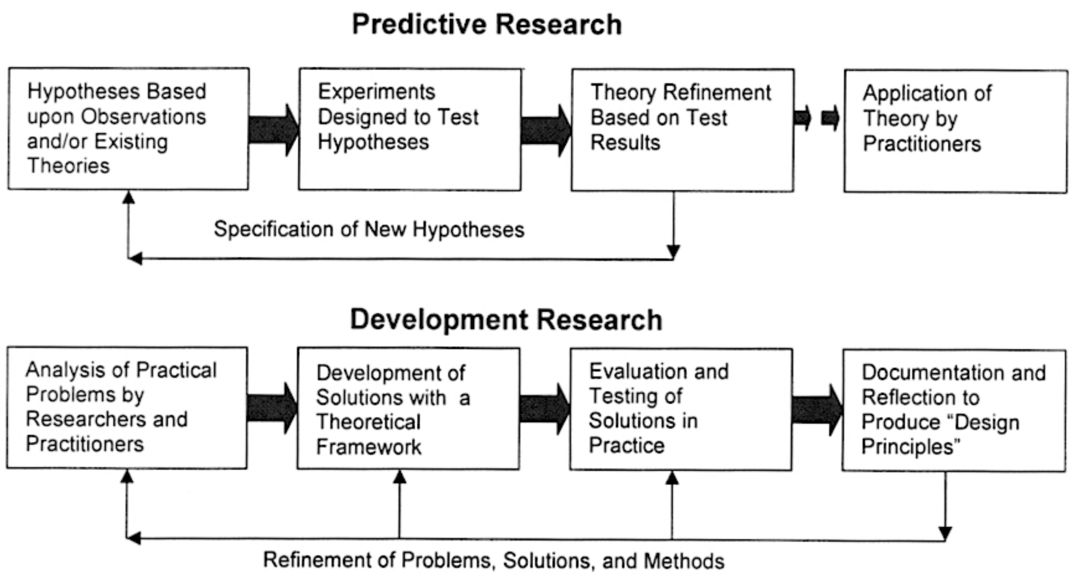

Figure 3: Alternative Research Concepts [27]

Figure 3 illustrates the differences in concept 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 empirical evidence for their effectiveness. It also assists in methodically evaluating the design and evaluation of such interventions.

THE EVALUATION INSTRUMENTS

The evaluation instruments are being developed in several stages.

a) Discussions with the teaching teams in engineering management and manufacturing systems are held to clarify and record the course objectives.
b) A clear view of the course objectives, establishes a base for specifying evaluation questions which can then be developed.

It is intended to focus on the comprehension and application levels of Blooms taxonomy [28], as these appear to be those levels with most application to the likely course objectives.

c) The data collection instruments to be used include; questionnaires, surveys, observation and interviews. In addition to these methods student records of current and historical coursework marks and pass percentages may be utilised.

PRELIMINARY RESULTS

Following 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 to discover what they felt about the use of the Team Detector scenario. Note: Assessment of the earlier ergonomics assignment has been published previously and will not be repeated here.

The interviews were designed to prompt the students to talk freely about the assignment and to 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, i.e. to a more relativistic stance. All but two of the students interviewed felt that the virtual factory format should be continued.

At the completion of the semester, the 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 commented 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 whilst they were carrying out the factory layout assignment, indicated that it was making them “think” about what they were doing rather than simply “plugging numbers into a formula”. They also felt that they were being forced into making difficult decisions which 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 done well and the students coped with learning the basics of Arena® with very little tuition time. The main problem faced by the students was in making a decision as to how long to run the simulation in order to get 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 get 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 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 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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