LEARNING STYLES AND LEARNING TO PROGRAM: AN EXPERIMENT IN ADAPTING ONLINE RESOURCES TO MATCH A STUDENT'S LEARNING STYLE

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ABSTRACT

This paper describes an experiment carried out to explore the relationship between a student's learning style and their success in an online module. This paper will describe the underlying architecture of the elearning environment and describe how a student's learning style is used to motivate the design of online module content. The system addresses the preferences of the auditory, kinaesthetic and visual learner.

A pre-test and post-test quasi experimental design was employed to examine the effectiveness of adapting module content to match a learner's style. Each student prior to taking the online module had to complete a learning style questionnaire. Depending on their learning style each student was then directed to a particular version of the module content designed to accommodate their preferred learning style. A pre-test post-test experiment was used as one measure of their performance during the module. The overall results will be presented and discussed. The student population is drawn from undergraduate computer science students completing their first Java programming module.

INTRODUCTION

The challenge faced by novice programmers is a topic that has interested researchers for the past four decades. Many approaches have been adopted to facilitate the learner. For example the Alice environment(1) provides an interactive 3D drag-and-drop interface for students; and JIVE provides an interactive visualisation environment for JAVA(2). Learning the semantics of a programming language is dependant on the student developing a mental model of the language constructs. It has also been suggested that there is correlation between a student's cognitive style and programming success(3). What implications do these developments have for programming teachers? As Henson has contested 'As a field of study, teaching methodology can not proceed any faster that the rate at which we improve our understanding of the learning process'(4).

The purpose of this paper is to describe an experiment designed to exploit one aspect of a student's self knowledge i.e. their learning style. Self-knowledge includes knowledge of one's strengths and weaknesses(5). The system presents content to the learner appropriate to their particular learning style. The expected outcome of any teaching process is that the learner learns. What influences how they learn is their individual learning style and so how an on-line course is designed, developed and delivered depends on that(9). This experiment shows that when a student is presented with material adapted to suit their learning style they are more successful. This paper concentrates on the design of the system and examines the results of the experiment carried out.

LEARNING STYLES

There are two major categories of learners, those who respond better to what they see are visual learners and those who respond better to what they hear are auditory learners. There are also the kinaesthetic learners, they learn by doing. But when faced with new information, the majority of people fall back on their dominant learning style. There are many different questionnaires and studies available that allows people to discover their preferred learning style. These learning styles then can be applied to work that is carried on in the traditional and virtual environments. The questionnaire that was used in this experiment was based on the Myers Briggs type indicator(7). Once the learning styles of the students were discovered module content was adapted to suit the three types mentioned above.

EXPERIMENT DESIGN AND DEVELOPMENT

Control Groups

The students log on to the system and are required to answer a series of pre-test questions on three different topics. The students learning styles are then determined using a learning style questionnaire. Each of the topics are adapted to suit a particular learning style. For example Topic 1 is adapted to suit the auditory learner, Topic 2 is adapted to suit the Visual learner and Topic 3 is adapted to suit the kinaesthetic learner. Once the learning styles are determined the students are presented with a series of pre-test questions on each of these topics. Once complete they are presented with three sets of lecture slides adapted to suit the three mentioned learning styles. The topic that was chosen for this particular project was Java programming and arrays. The reason that arrays were chosen was from previous research in that students experience difficulties in understanding the concepts of arrays and their associated processing algorithms(6). The topics are Sorting Arrays, Searching Arrays and the Software Development Life Cycle. Sorting Arrays will be adapted to suit the visual learner, Searching arrays will be adapted to suit the kinesthetic learner and the software development life cycle lecture will be adapted to suit the auditory learner, (**Figure 1**).

Topic 1	Topic 2	Topic 3
Sorting Arrays	Searching Arrays	SDLC
Visual learners	Kinesthetic Learners	Auditory learners

Figure 1: Topics

The students were expected to do better in the topic designed to suit their learning style. **Figure 2** predicts how the control group was determined. Auditory learners were expected to do better in Topic 3 which was the SDLC and the visual learners were expected to do better in Topic 1 which was sorting arrays and the kinaesthetic learners were expected to do better in topic 2 which was searching arrays The control group for the audio learners became the results from post questions on Topic 1 and 2. The control group for the visual learners were the results obtained from post questions on Topic 2 and 3 and for the kinaesthetic learner the control group were the results that the student obtained from the post questions on Topic 1 and 3. All of the students are measured on their success in all topics and results are compared. The student's population consisted of first years and second years from two institutes of technology in Dublin, Institute of Technology in Blanchardstown and the Institute of Technology in Tallaght.

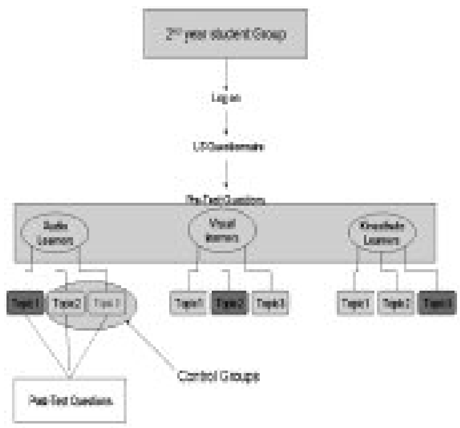


Figure 2: Control groups

The main focus of this project was to develop a system that analyzed, developed and implemented an adaptive elearning environment. Adaptive meaning that it adapts to suit the learners learning style and presents information to tem in a format that best suits them. Material that will be presented to them will include:

- Learning style Questionnaire
- Pre-tests
- Lectures
- Post-tests

The learning styles are determined and the course content is adapted to suit these learning styles. The results these questionnaires are then stored in a MySQL database. Students are required to complete a series of pre and post tests on each topic. These results are also stored in the database. The results of all post tests are also stored in the database and compared.

DATA ANALYSIS

The results in **Figure 3** depict the types of learners in the first group tested. This group consisted of 50 students. Out of these there were 5 invalid results so there are 45 valid results. The majority of students were kinesthetic learners and the minority were auditory.

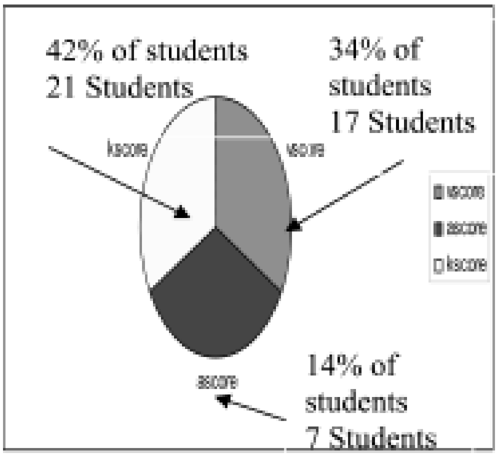
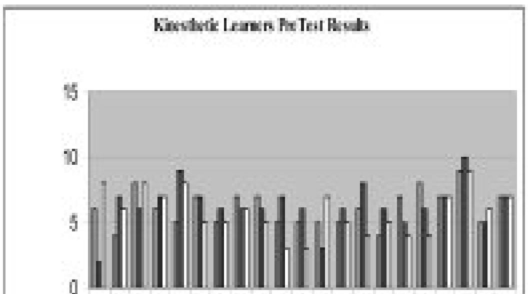


Figure 3: Data analysis

Kinaesthetic Learners

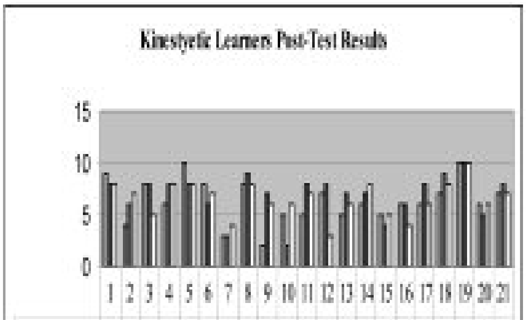
Table 1 represents the results of the students that were kinaesthetic learners. It shows how they did in the pre-tests for each of the topics. The topic that was developed to suit the kinesthetic learner was searching arrays the diagram shows that there are 21 students that



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PreSort	6	4	8	6	5	7	5	7	7	5	5	5	5	6	4	7	8	7	9	5	7
PreSearch	2	7	6	7	9	7	6	6	6	7	6	3	6	8	6	5	6	7	10	5	7
PreSdev	8	6	8	7	8	5	5	6	5	3	3	7	5	4	5	4	4	7	9	6	7

Table 1: Kinesthetic learners pre-test results

are kinesthetic out of this group of students. It shows how each student did in the pre tests for all subjects. There were 10 questions in each section. It was not expected that any student would get a 10 score in the pre-tests as some of them had read this information for the first time. There was 1 student who received a 10 score. The average result from the pre-search tests was **6.28**. The lowest score was 2 and the highest was 10.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PostSort	9	4	8	6	10	8	3	8	2	5	5	7	5	6	5	6	6	7	10	6	7
PostSearch	8	6	8	8	8	6	3	9	7	2	8	8	7	7	4	6	8	9	10	5	8
PostSdev	8	7	5	8	8	7	4	8	6	6	7	3	6	8	5	4	6	8	10	6	7

Table 2: Kinesthetic learners post-test results

Table 2 shows the results of the post search test results for the kinesthetic learner. The results are obviously higher looking at the graph. It shows how each student did in the post-tests for all subjects. The averages score from the post search tests was 6.9. Taking the first 4 students results and examining them it can be seen that there was a significant improvement. On closer examination it can be seen that some students made a significant improvement. For example the first student got 2/10 in the pre-test and in the post-test made a dramatic improvement to receive 8/10. The average result achieved for the first 10 students in the post-tests was 6.5. Out of the first 10 students 6 students made an improvement in the post tests.

Visual Learners

Table 4 represents the results of the students that were visual learners. The topic that was developed to suit the visual learner was sorting arrays.

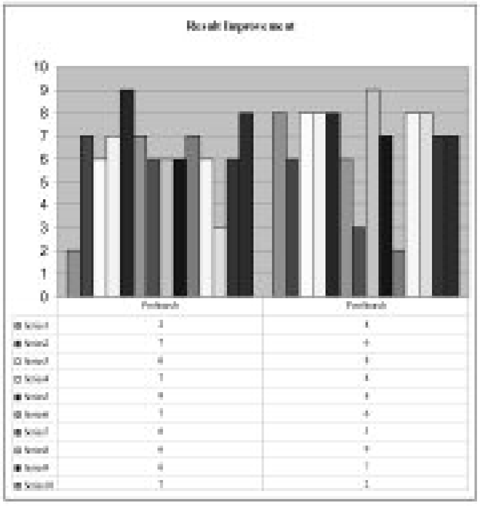


Table 3: Kinesthetic learners results improvement

Table 4 also shows that there are 17 students that are visual learners out of this group of students. The average result from the Pre-Sort tests was 6.05. The highest score was 8 and the lowest was 4.

Table 4: Visual learners pre-test results

Table 5 shows the results of the post-sort test results for the visual learner. The average score from the post-sort tests was 7.05 which is a significant improvement. The highest score was 9 and the lowest was 3.

On closer examination it can be seen that some students made a significant improvement. Out of the first 17 students 11 students made an improvement in the post tests.

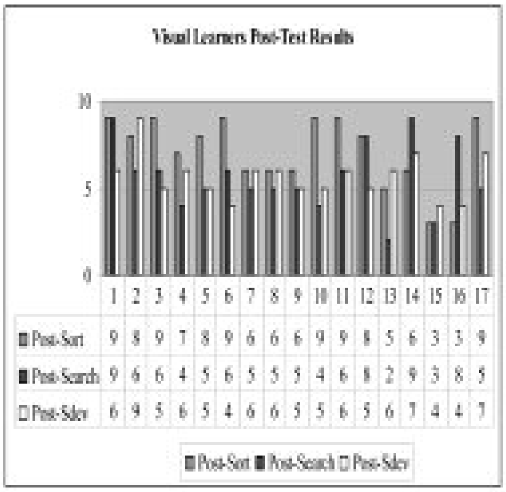


Table 5: Visual learners post-test results

Auditory Learners

Table 7 represents the results of the students that were auditory in their learning style. It shows how they did in the pre-tests for each of the topics. The topic that was developed to suit the kinesthetic learner was the software development life cycle.

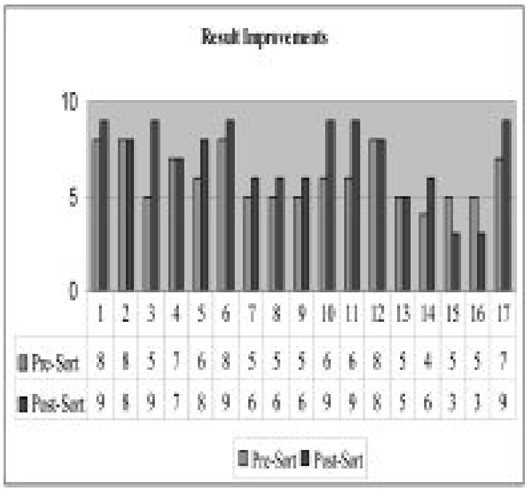


Table 6: Visual learners results improvement

There were only 7 students that were auditory learners out of this group of students. This is a relatively low number out of a group of 50 students. The topic that was adapted to suit the auditory learner was the software Development Life cycle. The average result from the Pre-Sdev tests was 5.28. The highest score was 7 and the lowest was 3.

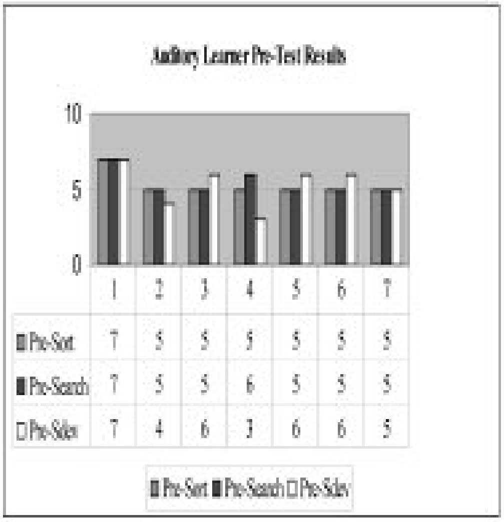


Table 7: Auditory learners pre-test results

Table 8 shows the results of the post-Sdev test results for the auditory learner. The results are obviously higher looking at the graph. It shows how each student did in the post-tests for all subjects. The average score from the post-Sdev tests was 6.6 which is a significant improvement. The highest score was 7 and the lowest was 6. On closer examination it can be seen that some students made a significant

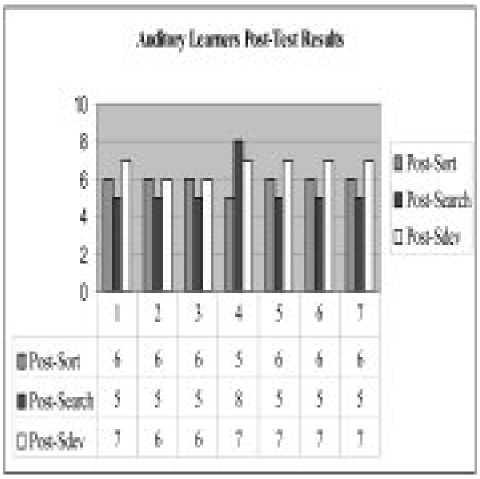


Table 8: Auditory learners post-test results

improvement. For example student number 4 went from 3/10 in the pre-tests to 7/10 in the post tests. Out of the 7 students 5 made a significant improvement in the post tests.

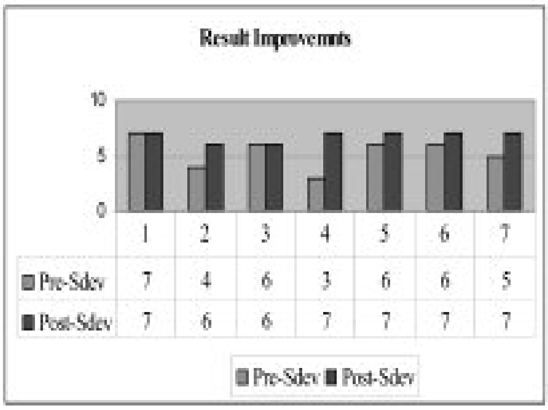


Table 9: Auditory learners results improvements

CONCLUSIONS

There are no national statistics, but a recent report in the Chronicle of Higher Education (United States) found that institutions are seeing dropout rates that range from 20 to 50 percent for distance learners(12). Frankola found that some of the reasons for this high drop out rate included lack of management, lack of motivation, problems with technology, lack of student support. An area that also appears to have contributed greatly to this drop out is Individual learning preferences and poorly designed modules. If content relating to a particular topic is designed to address the needs of a particular learning style you would then expect students with this learning style to be more successful. This project has been successful in achieving this. Students did well in all post test but made a significant improvement in the topic that was designed to suit their learning style.

The overall goal of this project was to observe elearning and distance education and to determine the relevance between the design of the system and the significantly successful outcome of presenting different system designs based on the learning styles of each of the users.

On studying the results of the project it can be seen that by introducing the use of learning styles combined with adaptive systems the achievement of the goals of distance education and elearning can be facilitated. One of these goals is a lower than average drop out rate. By providing these systems adjusted according to the different needs of different users this can be achieved. Such differences present a profound challenge for instructional designers and it is hoped that through further research that the quality of learning material is enhanced if the material is designed to take into account learners' individual learning styles.

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INNOVATIVE INTERNET E-LEARNING ON STEEL TECHNOLOGIES

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INTRODUCTION

Faced with increasing difficulties in recruiting graduates with sufficient knowledge of ferrous metallurgy and students lacking enthusiasm to join the steel industry, the International Iron and Steel Institute is developing an integrated Internet-delivered e-learning resource about steel – http://www.steeluniversity.org. The aim of this initiative is to educate and excite students and their teachers about steel and to provide cost effective materials for initial and continuing professional development for employees in the steel industry supply chain.

The heart of this website is a series of linked, highly interactive game-like simulations of the main steelmaking processes in which the learner takes control of a virtual steelworks. When completed, the learner will be able to produce steel from raw materials to rolled products. They take operational and technical decisions, respond to unexpected events as they occur and get feedback on the composition and quality of steel produced, time and temperature and the costs they have incurred. Several complex models are running in the background of these simulations to ensure that the learner experiences a realistic impression of the steelmaking processes in order to present to the learner a challenging and stimulating scenario that will enable them to apply important scientific principles to an industrial process within an economic framework. A detailed user guide is available on-line for each simulation and this can be used to help with the many calculations the learner has to make to run the simulation successfully. They are also supported by more conventional e-learning packages that allow the student to explore the underpinning thermodynamics and other scientific, metallurgical and engineering principles. Other modules address the design and selection of steels for different applications, e.g. construction and automotive. The website also provides on-line virtual mechanical property tests for strength, toughness and hardness and a module that explores the various ways of improving the properties of steels. Another deals with the important issue of sustainability and introduces life cycle assessment techniques with examples from the steel, construction and automotive industries.

The quality of steeluniversity.org was confirmed when it was selected as a recipient of one of the European Academic Software Awards, 2004. The jurors commended the website for its ‘Innovative and Excellent Graphical Simulations, Open-Ended Problems and Integrated Educational Approach’.

THE ELECTRIC ARC FURNACE

This is the first of a series of simulations of the major steelmaking processes. The Electric Arc Furnace (EAF) is essentially the major way in which steel is recycled at the end of its life, into a new product, often of a higher quality and for a more demanding application than it was previously used for. The learner has to make one of several steel grades (a construction steel, an ultra-low carbon automotive steel, a low sulphur linepipe steel or a low alloy engineering steel). After choosing the grade of steel they intend to make he/she then selects the quantity and type of scrap and other materials to use and identifies a charging policy for the scrap baskets and other alloy or slag forming additions. The raw materials then have to be distributed between the scrap baskets, taking account of the density differences between the various alloys selected. Provided the melting process has not commenced the student may add or remove materials until they are satisfied with their decisions and the expected resulting steel composition.

They then have to decide an action plan for their EAF process operation, including timing of the next basket of scrap steel to be charged,

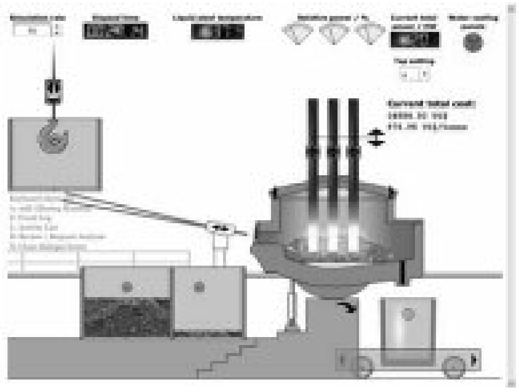

Figure 1: Melting of steel scrap in the EAF

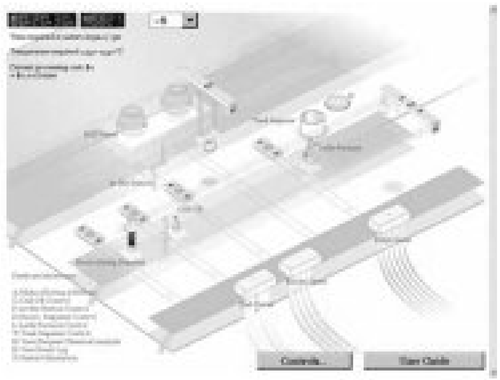

Figure 2: Virtual secondary steelmaking

turning power on or off, time to take a sample, the timing of deoxidation and other alloy and ferro-alloy additions and the time to inject oxygen or carbon and how much to inject. The student may change their process procedure at any stage, in the light of experience and other events. Some alarm warnings are available to the learner, e.g. cooling water temperature. **Figure 1** shows the scrap being melted.

When the required conditions have been satisfied the liquid steel has to be tapped into a ladle, in readiness for the secondary steelmaking processes that refine the steel further. The flexibility of the system allows the learner to define almost an infinite number of process routes and charging combinations. The objective is to meet the final requirements of steel composition, mass, temperature and time at minimum cost.

When the furnace has been tapped the student receives detailed feedback on how they have performed, in terms of the all the activities performed and the changes to mass, temperature and composition during the operation and comparing the tap time and temperature, mass and cast composition with the targets and a summary of the processing costs incurred.

Two levels of difficulty are available for students and graduate employees. The complications that the graduate may experience include short electrodes, electrode breakage, water panel overheating, and furnace over-filling. The simulation provides all learners with detailed operational understanding of the electric arc furnace and vividly illustrate how the EAF is a primary recycling tool, converting scrap steel into new prime product.

The steel produced in this simulation can then be further processed in the virtual secondary steelmaking and continuous caster plants.

SECONDARY STEELMAKING

The on-line simulation of a secondary steelmaking shop incorporates an argon-stirring station, ladle furnace, an RH degasser, a tank degasser and a CAS-OB unit, **figure 2**.

The learner has to make one of same four grades that can be made in the EAF (or Basic Oxygen Furnace, the focus of a simulation being developed currently) and is presented with a ladle of steel from the BOF or the EAF. Each grade presents a different technical challenge and requires a different process route. The learner must decide what additions to make, how to remove some elements, when and where to make them, which equipment to use and in what sequence, in order to get the ladle to the right caster within specification, at the required time, at the right temperature and at minimum cost. They also have to learn how to manipulate the cranes and ladle cars efficiently and also how to cope with unexpected interruptions and complications.

Supplementary learning packages are also available within this module that cover steel cleanness, deoxidation, desulphurisation, decarburisation and dehydrogenation, and the importance of slag composition.

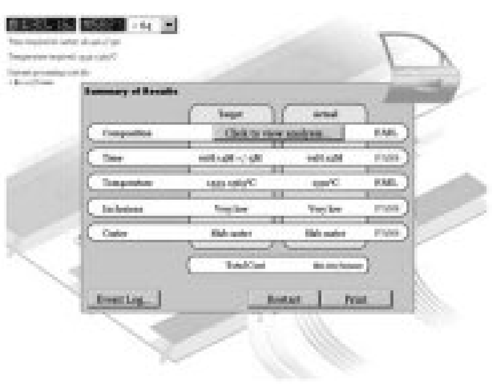

Figure 3: Feedback at the end of the secondary steelmaking simulation

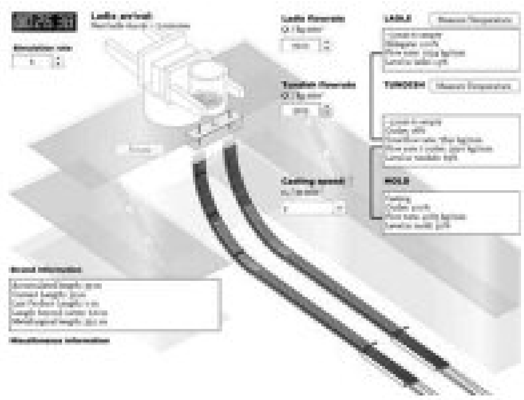

Figure 4: Virtual continuous casting

Again two levels of operation are available that are suitable for students and graduates in industry respectively. The former provides a basic functionality to enable them to understand and control the process principles, without too many operational complications, whilst the latter will also have to take into account and cope with practical disturbances that they had not planned for.

The end-point of this simulation is the delivery of the ladle of liquid steel to a slab, bloom or billet caster, depending on the grade being produced. It will be possible for the student to further process their steel through the continuous casting machine.

Feedback is given at the end of the exercise on how successful the student has been in meeting their objectives, in terms of the composition produced, the time and temperature at casting, the inclusion content and the costs incurred, **figure 3**.

The student can track the changes in chemical composition during their attempt and this can be used to help them analyse how to do better next time.

CONTINOUS CASTING

The on-line simulation of the continuous casting process can be run as a stand-alone exercise or can take ladles of refined steel produced by the learner in the secondary steelmaking simulation described above. Three casting machines to produce bloom, slab or billet are available, depending on the steel grade being produced and the application.

The user is able to study what happens in the tundish, in the mold and during the strand formation and cooling and be able to explore metal flow behaviour in the tundish and into the mold, inclusion removal, the role of tundish slag and mold flux powders, the effects of superheat, secondary cooling rates, mold stirring and casting speed, temperature changes, the formation of the meniscus, solidification, soft reduction, the origins of surface and internal strains, the formation of surface and internal cracking, causes and consequences of break-outs, segregation, steel cleanness and product geometry. The virtual continuous casting shop is shown in **figure 4**.

In operating the virtual continuous casting machine at steeluniversity.org the learner has many critical decisions to make. These include:

- Which grade of steel to make?
- Which product form – bloom, slab or billet?
- Ordering of ladles for sequence casting
- Operation of the ladle turret to change ladles
- Control of metal flow rates from the ladle to the tundish and from the tundish into the mold, through the use of slide gates and stopper rods
- Selection of mold powder
- Casting speed
- Mold oscillation

- Use of EMS
- Secondary cooling rate
- Use of soft reduction
- Control of roll alignment
- Cutting the cast product to the required lengths

During and at the end of the simulation the learner receives information on the temperature of the steel, flow rate selected, the levels of steel in the ladle, tundish and mold, the time left for them to empty at the current flow rate, and an indication of the surface and internal quality, inclusion content and extent of segregation, with a quantification of the number and length of cut strand and the costs they have incurred.

SELECTION OF STEELS FOR AUTOMOTIVE AND CONSTUCTION APPLICATIONS

The website has two modules devoted to the use of steel in two major market applications – construction and automotive sectors.

In the former, the diversity of steel types in construction are illustrated and the student has to identify the key requirements, properties and composition of some of these. The important design formulae are used and the student has to distinguish between elastic and plastic behaviour and between modulus and strength. The attributes of different structural materials are then studied. Some of the fabrication techniques used in structural steelwork are illustrated and the student has to select appropriate corrosion protection methods and finally the learner identifies the importance of steel to sustainable developments in construction.

In the other steel application module the student plays the role of a materials engineer in a multi-disciplinary project team, with the objective of selecting a material (a high strength steel) to reduce the weight of a car door by 25%, again at minimum cost. They have to address design issues and also the consequences of a higher strength steel on fabrication and manufacturing techniques such as forming and joining, as well as selecting the most appropriate corrosion protection method. **Figure 5** shows a formability test.

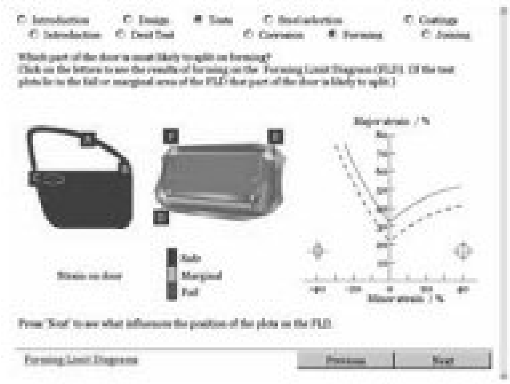

Figure 5: Formability tests on a car door

One of the steels that can be selected for this application is one of those that can be produced in the steelmaking simulations, one of the integrated features of this website.

MECHANICAL PROPERTIES OF STEELS

The importance of being able to understand specifications is covered in two modules on mechanical properties and engineering steels. An exercise is then undertaken in which the student has to take samples from a steel plate and undertake virtual tensile, Charpy impact, **figure 6**, and hardness tests, within time and budget constraints, in order to determine whether this particular steel is fit-for purpose for a ship application.

The module on engineering steels covers the selection and control of properties in carbon and low alloy steels and covers the effects of alloying elements on hardenability and temper resistance. The diversity of engineering steels and their specifications is highlighted, with sections on direct hardened, carburised and other surface hardened alloy steels, free-cutting steels, microalloyed forging steels, spring steels, ultra-high strength steels.

A subsequent module deals with strengthening mechanisms and ends with the learner designing and making a high strength steel for the energy industry. Again, this has to be done in such a way as to create a profit.

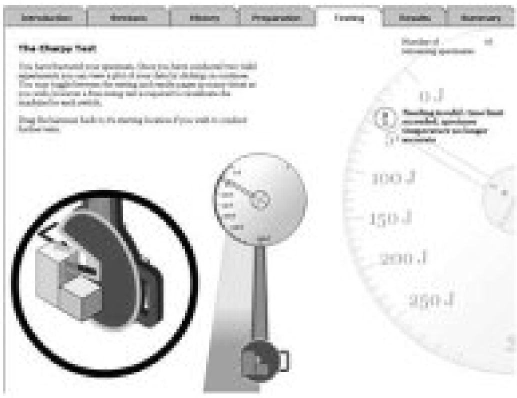

Figure 6: The virtual Charpy test

SUSTAINABILITY

Another module addresses sustainability, steel and the environment. The learner first examines the complex social, economic and environmental issues associated with sustainable development and the important role that steel plays in sustainable development. The IISI sustainability indicators are then introduced to the learner. The complexity of the environmental impacts caused by mankind and its activities are studied and then the principles of life cycle thinking are explored, with particular reference to the car as a product. The user then studies the procedures for undertaking life cycle assessments, with examples of their applications drawn from the automotive, construction and steel industries. The aim is to give them the confidence and inspiration to use these techniques and philosophies in their decision-making concerning jobs and life styles.

USING STEELUNIVERSITY.ORG

steeluniversity.org has been designed to supplement traditional teaching and learning methods as part of degree courses and training and professional development programmes in industry. A blended (alloyed) learning approach is ideal, in which these resources can be used as self motivated or directed learning. The simulations have also been used highly effectively as competitions for individuals or teams. The simulations and other exercises are excellent for problem-based learning experiences. The car door steel selection exercise is used as the basis for an undergraduate team project, Anderson(1). The certificates that can be printed at the end of each simulation and major exercise can be used to record and validate a learner's achievement.

A global Internet 24 hour competition based on the secondary steelmaking simulation was run at the end of 2005. This attracted over 200 entrants from students and steel industry employees on 5 continents. Most of the contestants made several attempts, each time trying to improve on their quality and then reducing their costs – an excellent example of continuous improvement. The best student was in third place overall and 2 students featured in the top 10 candidates. This competition will become an annual event, which in future will involve more complex integrated challenges.

Over 50 universities and 25 companies worldwide are known to be using the steeluniversity.org resources and visitor numbers to the website are 40,000 per month.

In order to increase its use internationally, steps are being taken to make steel-university.org available in different languages. Some of the modules are now available in Spanish and Chinese and more are planned in the future.

FUTURE DEVELOPMENTS OF STEELUNIVERSITY.ORG

Over the next three years, it is intended to add new resources to steelunversity.org with simulations of the Blast Furnace, BOF, hot and cold rolling. These will be fully integrated so that the learner will be able to produce and roll their own steel from either scrap or iron ore in the virtual steelworks at steeluniversity.org. Other modules are being created on the design and selection of steels for power generation, environmental management in the steel industry, phase transformations and heat treatment, recrystallisation and grain growth.

It is also planned to introduce an on-line database of expertise involved with the teaching and researching on steel technologies in academia and steel companies and research institutes, in order to facilitate knowledge and technology transfer and cooperation between steel industry and academia.

steeluniversity.org is an award winning, ambitious, freely available, Internet initiative being undertaken by the IISI with the help of experts around the world on steel technologies. It provides highly interactive simulations of the major steelmaking processes and exercises on the selection of steels for important applications, together with an understanding and implementation of the underlying scientific, engineering and metallurgical principles. These resources are aimed at raising awareness and interest in students and their teachers about steel and providing valuable, low cost training and continuing professional development resources for employees in the steel industry supply chain, ideally formally integrated into their curricula, in-house courses and learning management systems. The simulations, either singly or in combination, can be used as a basis for competitions between individuals or teams.

Universities, steel companies and their suppliers and customers in all parts of the world are already using steeluniversity.org effectively to enhance and sustain knowledge of ferrous metallurgy and to excite young people about steel.

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STUDENTS' IMPRESSIONS OF A HYBRID REAL AND SIMULATION LABORATORY

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Keywords: laboratory, collaborative, cross-disciplinary, virtual

ABSTRACT

Providing laboratory classes to engineering cohorts can be an expensive process, particularly when industrial hardware is required. A shift to virtual laboratory classes is an attractive alternative that can reduce the cost of laboratory classes, but it is important to consider the impact such a change has upon the students.

This paper describes the use of a hybrid real and virtual laboratory class at Curtin University of Technology. This class takes advantage of the modular, roll-in roll-out trolley system used in the Faculty of Engineering's Programmable Logic Controller laboratory, allowing a computer-based simulation of the hardware involved to be integrated with little difficulty. This allows for the students to access virtual laboratory hardware at any time, transferring the initial familiarisation phases of the laboratory projects away from a hands-on, synchronous experience to a simulated asynchronous one.

Surveys of the students' experiences show that they are supportive of the new laboratory facility, and that they predominantly regard their hybrid virtual-and-physical laboratory experience as being real.

INTRODUCTION

Laboratory classes are an important part of undergraduate engineering education. They serve a number of valuable roles, such as validating analytical concepts, and providing exposure to professional practice(1). One of the drawbacks of laboratory classes is that they are expensive. A significant proportion of this investment is the cost of hardware for the laboratory class. This cost can be reduced by building facilities that can be shared by multiple departments for multiple laboratory classes. Another avenue that can potentially reduce this cost is to move to virtual laboratories, and potentially remove the need for the hardware entirely.

Curtin University of Technology has recently built a shared laboratory facility for Programmable logic controllers (PLCs). PLCs form part of the curriculum for multiple engineering disciplines, each of which makes use of laboratory classes as an instructional method. Whilst the specific contexts of the laboratory classes differ, there is substantial overlap in the hardware requirements of these laboratories - and this overlap provides an opportunity to reduce the cost of providing laboratory classes.

For the laboratory work in Mechatronic engineering, computer simulations of the laboratory equipment have been introduced to create a hybrid mode laboratory class. Students interact with both real and virtual hardware throughout the course of the laboratory. The students' impressions of this hybrid approach were measured using feedback surveys, with their perceptions midway through semester compared to those at the end.

Presently only the Mechatronic Engineering program includes hybrid mode laboratory classes, although other departments are planning to implement them in the near future.

THE FACILITY

The laboratory class is held in the Engineering Faculty's shared PLC laboratory. This facility exploits the significant overlaps in the resources requirements of the three departments conducting PLC laboratory classes.

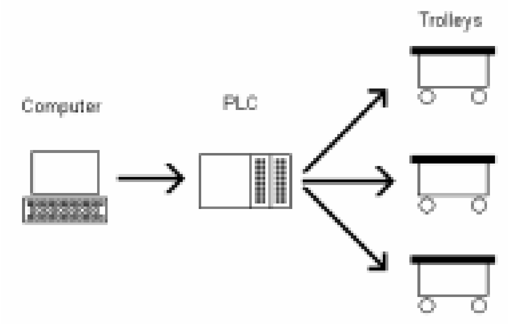

Figure 1: Modular layout of laboratory

Each of the departments using the facility has different contexts in which they employ PLCs. For the electrical engineering department, the PLCs are used for controlling a simulated elevator, and also a traffic light control rig. The Mechatronic Automation course uses the PLCs to drive pneumatic hardware, while the Chemical Engineering students use the PLCs for flow control between water tanks.

Whilst there is great variety in the overall use of the PLCs, the hardware requirements differ only in the nature of the hardware to be controlled. The PLCs themselves, and the PCs required to program them, remain common to each of the configurations (**figure 1**).

To exploit this commonality, the design of the PLC laboratory has been centred on trolley-mobile hardware rigs. The laboratory itself is very similar to a standard computer laboratory, with PC workstations along two walls (see **figure 2**). Where the layout differs is through the inclusion of pneumatic power supply from the roof and walls, and the presence of a water supply and sink at the end of the room.

Figure 2: End view of laboratory

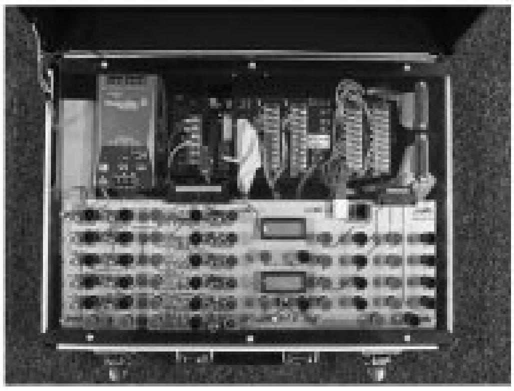

Figure 3: Briefcase-mounted PLC

Each of the PLCs has been housed in a metal briefcase, with custom input-output fixtures. This allows for data to be communicated to the PLC either as single bits or through ribbon cables for entire bytes (see **figure 3**).

The PLCs are Ethernet-enabled, allowing for each PLC to be accessed from each of the workstations within the laboratory. This allows the flexibility to designate a PLC to a particular workstation, for the use of a specific group of students, or to designate it to a particular piece of hardware, to be shared by all students.

The PLCs are connected via cables to the specific hardware, with the nature of the connection dependent upon the I/O requirements of the rig in question.

The trolleys (the Mechatronic Engineering trolleys are shown in **figures 4 to 6**) are stored in a cage next to the laboratory. At the beginning of the class, the demonstrator unlocks the cage and wheels in the trolley(s) appropriate to the class. The trolleys are then locked away at the end of the class.

VIRTUAL HARDWARE

The modularisation of the laboratory class has enabled the facility to make shared use of PC and PLC hardware. This modular nature also opens up another educational possibility – that of virtual hardware. The operating model of the laboratory is one of interchangeable trolleys, each of which corresponds to a different laboratory class. The extension is to make a 'virtual trolley', where a hardware-in-the-loop

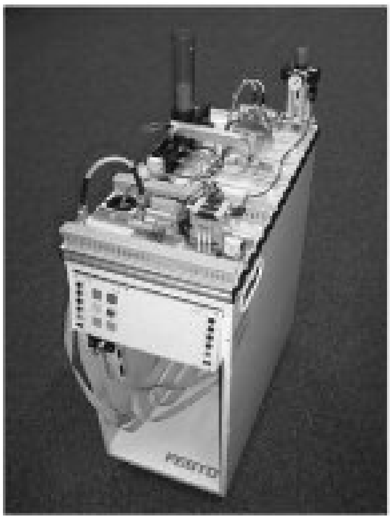

Figure 4: Distributing trolley

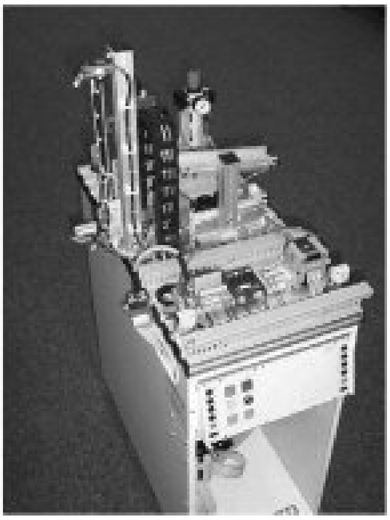

Figure 5: Testing trolley

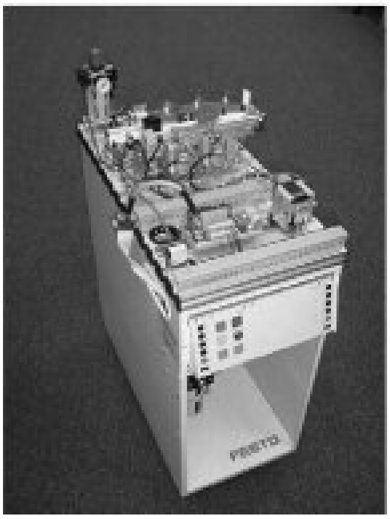

Figure 6: Sorting trolley

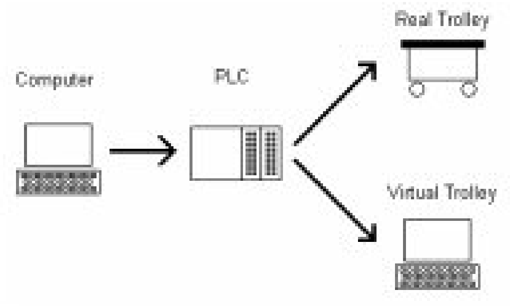

Figure 7: Virtual trolley module

simulation is used to provide an alternative to the real equipment (**figure 7**).

The pneumatic hardware used by the Mechatronic engineering students is manufactured by FESTO, who also provide a simulation environment (named CosimirTM) in which their equipment can be modelled. Cosimir allows for much of the operation of the hardware to be replicated without the need for the physical hardware to be present (**figure 8**).

The implementation of a site license for the simulation package reduced the amount of physical hardware that was necessary for the laboratory class – rather than purchasing one trolley per workstation, instead a total of six trolleys were purchased to be shared amongst the class. This introduced an element of queuing, in that there were often more groups wanting trolleys than there were trolleys available, however there was seldom an issue with expensive equipment lying idle.

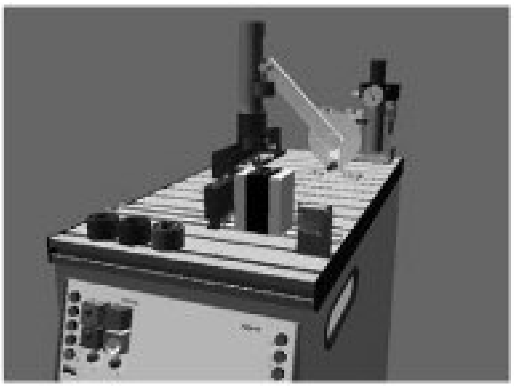

Figure 8: Distributing trolley in Cosimir

Previous studies into the use of virtual laboratory hardware show that there are changes to the students' learning outcomes(2) and their perceptions of these outcomes(3). A key aspect of these changes is in the students' changed perceptions of their learning environment – changes in way in which they engage with the laboratory experience. Simulated laboratories expose the risk of the students becoming detached from the real hardware that is being simulated, and instead focusing upon the decontextualised interface.

In order to mitigate this risk, the students were exposed to the physical hardware at the same time as the simulation – whilst they worked on simulations on the computers, the physical trolleys were also present in the laboratory, allowing the students hands-on access whenever they wished it.

STUDENT RESPONSES

In order to evaluate the impact of the hybrid access mode upon the students' perceptions, the students were surveyed twice in the semester, once at the halfway point and again at the conclusion of the semester.

For the first six weeks of semester, the students were restricted to using the simulation. Whilst the trolleys were present in the laboratory, and the students were welcome to interact with them in order to assist them in their visualisation and familiarisation, the hardware was not connected to the PLCs or to a power supply. From week seven onwards the students were able to implement their simulation-developed code on the real hardware.

The first survey was taken in week six of semester – the last week before the students were allowed to start using the real hardware, and as such the students' perceptions at this time reflect no actual hands-on use of the physical hardware. Despite this lack of direct interaction, however, the laboratory still registered as 'real' for a majority of the students (**figure 9, figure 10**).

Throughout the second half of the semester, the students were allowed access to the real hardware, but their primary method of developing solutions was through the use of the simulation. Despite this develop on simulation and test on real approach, at the conclusion of the semester the students almost unanimously regarded their laboratory experience as being real (**figure 11, figure 12**).

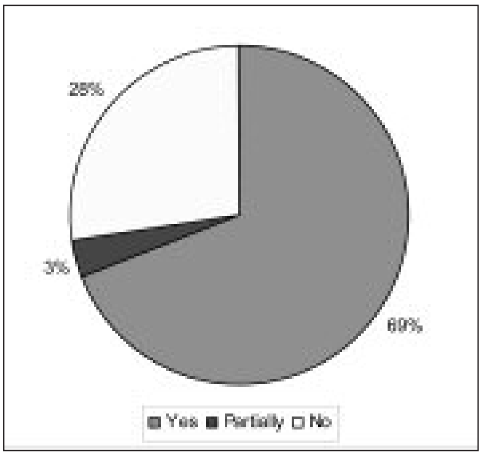

Figure 9: Did you feel you were controlling real hardware? – Week 6

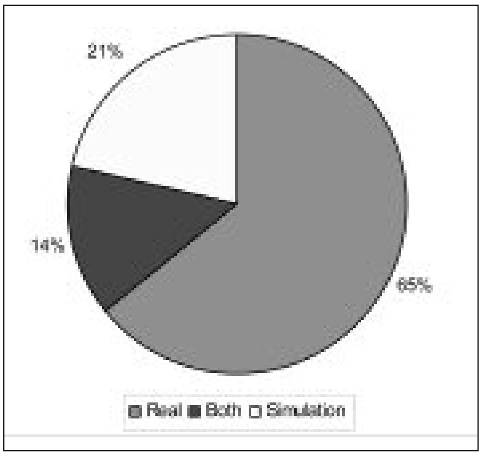

Figure 10: Which do you picture in your mind? – Week 6

Students were also asked to reflect upon the hybrid approach to the laboratory environment, and whether they found it helpful. The majority of the students (73%) indicated that they had found it helpful (**figure 13**).

Significant to note is that 32% of the students who responded referred to the differences between the simulation and the real hardware – although this was given both as a negative and a positive of the hybrid approach.

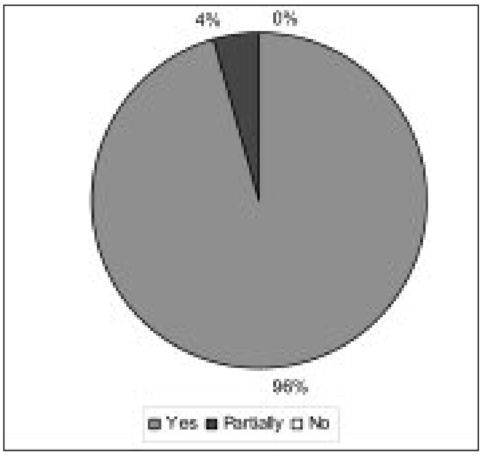

Figure 11: Did you feel you were controlling real hardware? – Week 12

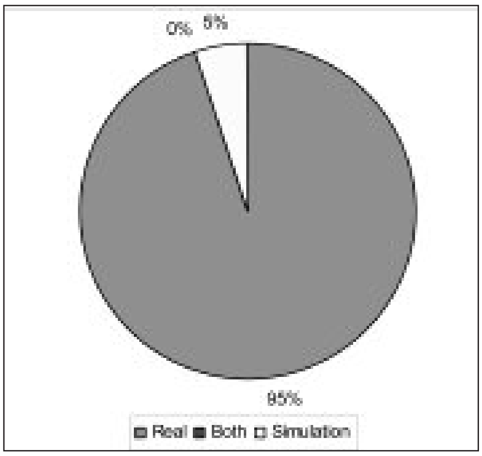

Figure 12: Which do you picture in your mind? – Week 12

These responses show that the despite the students interacting with the simulated hardware, they still regard the experience as being real overall, and that they are aware of the differences between the simulation and the physical hardware that it represents.

CONCLUSION

Curtin University of Technology has successfully established a hybrid simulation-real mode laboratory class for Mechatronic engineering. Student responses of the initial cohort show that despite a large dependence upon the simulation environment, the laboratory class is still overwhelmingly perceived by the students as being "real", suggesting that one of the major drawbacks of virtual laboratory classes has been overcome.

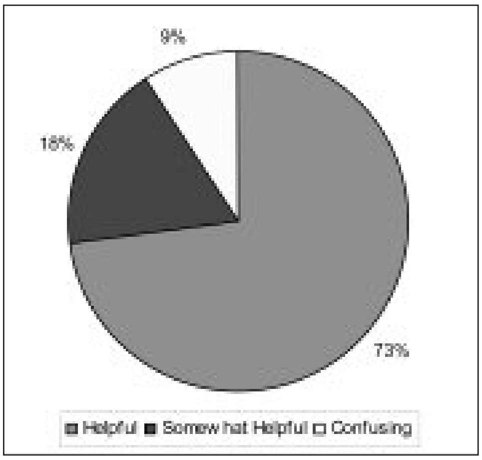

Figure 13: Did you find the hybrid mode helpful?

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THE DEVELOPMENT OF A SIMULATION ENGINEERING GAME TO TEACH PROBLEM SOLVING SKILLS AND TEAM DYNAMICS

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Abstract

Simulation technologies have become the corner stone of many training programs, from simple game–playing scenarios to totally immersive virtual reality simulators. However, many of these simple teaching aides merely tend to develop the manual dexterity of the learner. The game described in this paper develops the learner's problem-solving skills and teamwork. The game under development is based on a simulated production line, constructing structures with Lego blocks. The game has three discrete phases; each with a briefing session, a production 'run' and a debriefing session. It encourages observation and discussion of possible improvements required to increase productivity. This is achieved by the learning of good team interaction and the application of different problem-solving techniques. Initial feedback from students reveals that the simulated game provides a better method of observing the importance of team dynamics and the honing of problem solving skills.

INTRODUCTION

Engineering educators are evolving from the more rigid theoretical delivery of knowledge to an application, problem-based learning environment. This has, in part, resulted from the demand from industry that requires graduate engineers to 'hit the ground running'. Today's problem-based learning curricula hope to fulfil this need by equipping graduates with a number of people and professional skills, e.g. effective teamwork, problem solving skills, communication skills, etc. In many instances, simulators have provided an excellent learning tool in providing realistic working environments for:

- the training of machine operation,
- what-if and cause and effect scenarios,
- logistics and operational management.

Simulated training has long been the most cost effective and efficient form of learning machine operation and manual dexterity. The complexity and cost of these simulators are in direct proportion to the safe operation of the machine, e.g. the multi-million dollar flight simulators to train commercial and fighter pilots to the relatively cheap computer-games type simulations. Recent advances in computer technology have provided for more realistic virtual reality simulators; from the totally immersive CAVE (Computerized Automatic Virtual Environment) simulators(1) to precision surgical simulators with tactile – force feedback(2).

A number of educators have reported promising results from the use of virtual labs, simulation software(3) and remote access laboratories(4). All reported that the theoretical knowledge has been greatly enhanced by the undertaking of some form of experimentation and exploration.

Simulation is ideally suited to situations where the size and cost of some systems cannot be replicated in educational institutions; e.g. large-scale production facilities and manufacturing processes.

This paper describes a very basic simulation game, which not only enhances the understanding of production systems, but also provides a means of developing teamwork and problem solving skills.

THE SIMULATION GAME

The game has been adapted from a simulation game developed by QMI Solutions to help manufacturers and industry increase capability, productivity and capacity by applying World Class and Lean Manufacturing techniques. The game simulates an assembly process (but can be used to represent any process or service) and focuses on the 'theory of constraints' to identify and eliminate inefficiencies in the production process.

The game is based on the assembly of a product; with the individual components being LEGO building blocks. The production/ assembly line comprises a number of work-stations; including an issue store, assembly stations, where building blocks are added to the assembly, and quality control stations. To make the production line more 'realistic', special jigs and fixtures are incorporated at two stations to represent processing machines used on the production line. The game is conducted in three distinct phases (or production runs) with a briefing and a debriefing session at the start and end of every run, respectively. It is during the debriefing session that the students get to develop the teamwork and problem solving skills together with exploring and experiencing World Class and Lean Manufacturing tech-niques. These techniques include:

- Waste reduction
- Just-in-time (push/pull) systems
- 5S's of housekeeping
- maintenance planning
- factory layout
- supply chain management

(This paper will not discuss these techniques. Contact the authors if you require more information.)

The expected outcomes of this simulated engineering game, which would be conducted as a series of short workshops, are:

- Awareness of Best Practices of World Class Manufacturers
- A greater understanding of production environments
- A greater appreciation of team dynamics
- The honing of problem solving skills
- The important of a clean and structured work environment (through 5S's of housekeeping)
- Application of these principles to everything we do.

This paper describes the results from a few pilot trials which were conducted to validate these expectations. The assessment and analysis of data is on-going and will be published shortly.

The first workshop presents the manufacturing environment for the 1st production run.

The 1st Production Run

A very short briefing session is provided before this production run. Each simulated run lasts for 15 minutes. In this time the students, working at their workstations, are required to produce 10 batches (1 batch = 10 assembled products) in a time of 15 minutes.

Being the first run, the facilitator has total control, and creates as many obstacles to a successful run as possible. These include:

- Very poor product flow through the assembly line; (see **figure 1**)
- Simulated machine breakdowns
- Provides poor instructions for quality control;
- Paperwork: Requisition form that need to be completed and signed by the super-visor before the issue of parts and spares
- Every station is required to work as fast as possible
- A cluttered, untidy work environment

During the pilot trials of this game, students only succeeded in producing an average of 2 batches at the end of this 15 minute production run.

DEVELOPING TEAM SKILLS

At the end of the 1st production run, the facilitator informs students that they would be allocated into one of four 'production consultant' teams. The facilitator then provides some guidelines as to what constitutes a 'good' team(5). These include:

- Team leadership
- Functions of a team leader (to act like 'blotting paper' and draw out ideas from the team members and promote discussion within the group.
- No criticism of members' ideas
- Every member to contribute without comment of interruption from the other members
- Team members co-operate rather than compete

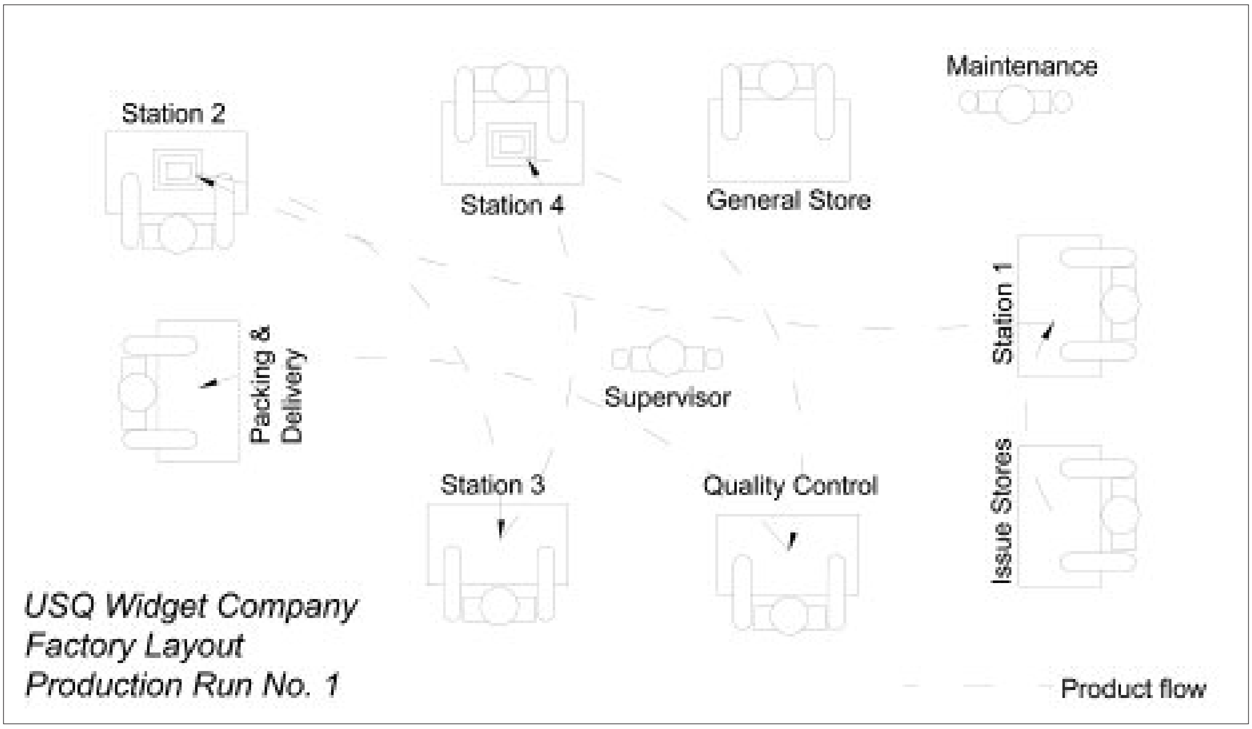

Figure 1 : Diagram illustrating the layout of the work stations for the 1st production run

- How to deal with conflict
- Decisions are based on consensus
- How to record discussions and compile a feedback report.

The facilitator then asks each team to discuss the reasons for the poor output of the 1st production run, and ways in which the assembly process can be improved to meet the production target. Note that the facilitator has not provided any reasons why the 1st production run failed to meet the target. This encourages the team to engage in open discussion and exploration of ideas. The teams are given 15 minutes to discuss the production process. The facilitator and his assistants initially observe the interaction within the team to ensure that guidelines for effective teamwork are followed, and would prompt further discussion if any group has exhausted their ideas.

Following this team involvement, the team leaders present their team's findings and suggestions. The presentation also provides for enhancing verbal presentation skills. During this open discussion, the teams compare notes and devise a plan of action to improve the assembly process. The more important aspect of this phase of the game is that the team members get to reflect on the leadership, interaction, conflict resolution (if any) and team dynamics. The teams get to share their experiences with everyone.

The 2nd Production Run

The students now have control over the work environment, and implement their ideas for a more efficient run. Piror to the start of this run, the facilitator prompts further discussion as to what can be measured to quantify the assembly process. Students generally decide to measure the time for assembling a single unit, which they would use to benchmark this process. Also measured are times lost in machine breakdowns and machine maintenance. At the conclusion of this run, students produce only 8 batches.

DEVELOPING PROBLEM SOLVING SKILLS

With the students in their teams, the facilitator discusses the different problem solving techniques that can be used to analyse problems and develop solutions. These include:

- brainstorming techniques,
- Ishikawa (fish-bone) analysis,
- Pareto analysis, and
- SWOT analysis.

The team members are issued with a Problem Solving Worksheet(6) which specifies six steps to be followed. These are:

Step 1. Recognise the Problem - For a physical activity, this would require the student to observe the situation (look, listen, feel, measure)
Step 2. Define the Problem: There is no one definition of a problem – Examine all the angles; stay open to all possibilities(7). This step requires the student to answer the 5W's + H (what, where, when, who, why and how).
Step 3. Collect Information: Strong decisions require strong data. This may require research into and measurement of critical activities and machine processes.
Step 4. Problem Analysis: using one of the problem solving techniques.
Step 5. Select the best solution: team to reach consensus on the solution that is best suited to solving the problem.
Step 6. Implement and monitor the solution: this would provide a measure of the effectiveness of the solution, and refine further improvements to the system.

The teams are now required to choose an appropriate technique and analyse the causes for not meeting the target and what can be undertaken to improve efficiency. At this stage of the game, the improvements relate to more complex manufacturing theory and World Class Manufacturing Techniques. The facilitator would provide more cues to focus the students' attention along these lines.

After a period of 30 minutes, the team leaders (or any other nominated team member) make a presentation of their results together with an explanation of the problem solving tool that they used. After the open discussion on the issues of the assembly process, the students once again are asked to reflect on the different problem solving skills that they employed. During this session, the students get an insight to how the other teams approached the problem and the methodology that they used to solve the problem.

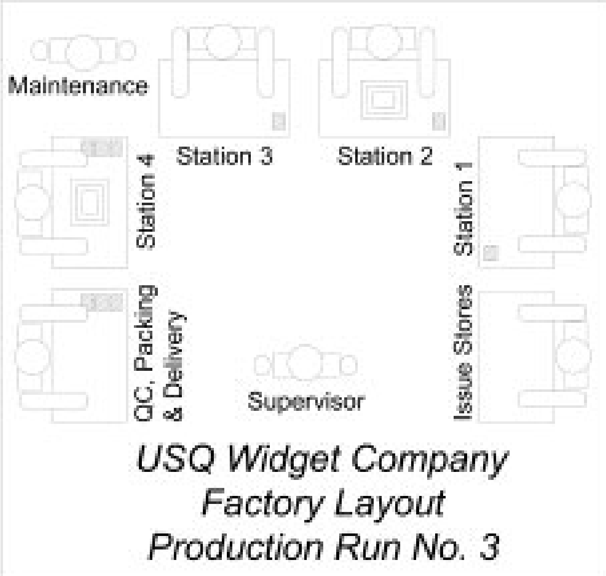

Figure 2: Layout incorporating World Class Manufacturing Techniques of efficient product flow, Just-in-time (kanban) system and elimination of 'waste'

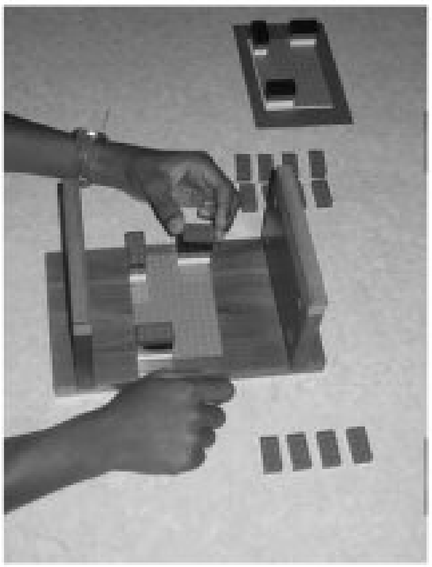

Figure 3: Photograph of Station 4 showing the wooden jig which represents a machine. Note also the kanban card (top right of picture) which controls the flow of the products

The Final Production Run

The students now implement their ideas and conduct the final production run (Refer to **figure 2 and figure 3**). During the pilot trials, all groups achieved the target output within the allocated time. It must be noted that the improvements implemented to the assembly process were solely the students' ideas and initiatives, and these evolved within teams and with the use of problem solving techniques.

DISCUSSION AND FUTURE WORK

At the final de-briefing and reflection session, the students unanimously stated that they have a greater understanding of team dynamics and or more motivated and confident about using the various problem solving techniques. A common response was that they 'theoretically' knew about these skills but only appreciated its impact once they employed these skills in a 'real' situation.

The Faculty of Engineering and Surveying at USQ are spearheading the drive to provide many problem-based learning courses, both for on-campus as well as distance (external) students(8,9). Most successful are the suite of four core Engineering Problem Solving courses. Students undertake one level of the course in each of their four year program. To succeed in these courses, students must work in effective teams and be able to solve various 'real' engineering problems. It is hoped that the introduction of this simulation game will provided more skills to the students to enhance the study of these problem-based courses.

As this paper reports the discussions following a series of pilot trials of the simulation game, the next stage being developed will attempt to quantify the impact that this game has on the learning and application of these skills.

To cater for the external student cohort, a web-based version of this program is being developed. It would be integrated with 'Arena' simulation software which will provide an on-screen simulation of the assembly process. The students would then follow the above procedures for enhancing their team and problem solving skills. This interaction would take place via USQStudyDesk which provides a computer portal for all students undertaking the course. The StudyDesk uses the e-learning system WebCT, which has been successfully implemented to deliver courses to both on-campus and external students(10).

The simulation game could be ideally used as an ice-breaker activity in a team-based problem-based learning course. This would allow students to get to grips with some of the issues of teams and problem solving in a 'fun', before they apply these skills to coursework.

The game is also planned to be played at schools, initially with yr 10-12 students undertaking Industrial Technology, and then later as a general team building and problem solving workshop. The vision that the authors are focusing on, is the providing the engineering game as a learning tool kit, together with instruction manuals on how to conduct the workshops. In this way, teachers will be able to use the game kit whenever and wherever they perceive that this learning style will have an impact.

CONCLUDING REMARKS

The game described in this paper develops the learner's problem-solving skills and teamwork. It uses very basic materials to simulate an assembly line where students can experience a real-life scenario. This game has several applications including uses in PBL courses and other activities in schools.

ACKNOWLEDGEMENT

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KEYNOTE PLENARY
THE INVOLVEMENT OF INDUSTRY IN ENGINEERING PROGRAMMES

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ABSTRACT

Engineering is a vocational subject, our degree programmes provide an educational base for students to progress into a broad range of careers. Input by practioners from industry has long been recognized as having a positive impact on student learning: industry involvement is embedded in the Engineering Council's accreditation documents and numerous national reports in the UK have highlighted the need for stronger links between industry and higher education, as well as a need for all students to be employable through the acquisition of transferable skill.

Industry can have an input into student learning on many levels. For many years the author has provided, tutored and assessed undergraduate design projects in collaboration with practitioners from industry. Industrial advisory panels and sponsors' consortiums afford valuable input into curriculum design and industry placements for students, as part of their degree programme, reinforces learning and offers practical experience. The benefits that students derive from contact with industry can be clearly articulated. However, there are practical problems for industry in releasing staff; time is money, so industry must also see benefits which can include access to potential graduate employees and professional staff development through involvement in teaching,

This keynote will describe a range of examples of industry input into teaching from the seven subject areas that were awarded the Centre for Excellence in Teaching and Learning (engCETL) at Loughborough University. The work of the engCETL to support and facilitate further innovation and to embed and disseminate good practice, underpinned by pedagogic research, will also be covered. The broad theme for the work of the engCETL is 'industry linked engineering education' and this includes the continuing development of e-learning tools that support student learning in both the university and the workplace.