The Use of Simulation Games to Enhance the Understanding of Manufacturing Processes.

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Abstract: *Simulation games are 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. Students undertaking a course in Manufacturing Processes participated in a role-playing game within a simulated manufacturing environment for the production of LEGO widgets. The game had 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 paper describes the exceptional learning outcomes achieved, the explicit understanding of manufacturing strategies and an insight into the approaches taken by world class manufacturers to maximise production. Surveys of students, taken before and after the game, revealed that they gained a greater appreciation for the course content by being immersed in this game scenario. This simulated experience may result in an easier and more informed transition into the real world of manufacturing. The game also illustrated the importance of good team interaction, the application of different problem-solving techniques, and proved the old adage "work smarter not faster".*

Introduction

Engineering educators are evolving from the more rigid theoretical delivery of knowledge to an application-based, problem solving learning environment. This move has been further driven by today's students; the majority being Generation Y's – the "Millennials". In her papers "Understanding the New Students" and "Educating the Net Generation", Diana Oblinger (2003, 2005) states that the Millennials prefer experiential, interactive and authentic learning. She further states that learning undertaken in simulated or games environments appear to be more effective for this generation of learners as it helps them to visualize complex systems. There are a number of attributes of simulation games that make them good educational tools; they often involve problem-solving and decision making, they provide rapid feedback and they allow for varying degrees of complexity or levels of difficulty. The Millennials have grown up with computer games, Nintendo's, and Playstations and it seems a logical use of this environment for their education.

The traditional approach to teaching manufacturing processes in universities is by classroom lectures, in which students passively receive information from the instructor and do not have opportunities to develop first-hand experience of the application of manufacturing techniques (Fang, 2009). This is further compounded by demands from industry that require graduate engineers to "hit the ground running". . Today's problem-based learning curricula aims to fulfil this need by equipping graduates with a number of people and professional skills, such as effective teamwork, problem solving skills and communication skills.

In many instances, simulators have provided an excellent learning tool in providing realistic working environments. Simulated training has long been the most cost effective and efficient form for 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. Recent advances in computer technology have provided for more realistic virtual reality simulators; from the totally immersive CAVE (Computerized Automatic Virtual Environment) simulators (Preddy, 2002) to precision surgical simulators with tactile – force feedback.

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. A number of educators have reported promising results from the use of virtual labs, simulation software (Scott, 2004) and remote access laboratories (Trevelyan, 2003). All reported that theoretical knowledge has been greatly enhanced by undertaking some form of experimentation and exploration.

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 (Pather, Aravinthan, 2006).

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 workstations; 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 while exploring and experiencing World Class and Lean Manufacturing techniques. These techniques include:-

- Waste reduction
- Just-in-time (push/pull) systems
- 5S's of housekeeping
- Maintenance planning
- Factory layout
- Supply chain management

The 1st Production Run

A very short briefing session is provided before the 1st 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 (playing the part of an autocratic, production-driven manager of the company) 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
- Poor instructions about quality control;
- Paperwork :- Requisition forms that need to be completed and signed by the supervisor before the issue of parts and spares
- Emphasis on speed; every station is required to work as fast as possible
- A cluttered, untidy work environment

At the end of this first run, students only succeeded in producing, on average, 2 batches at the end of the 15 minutes.

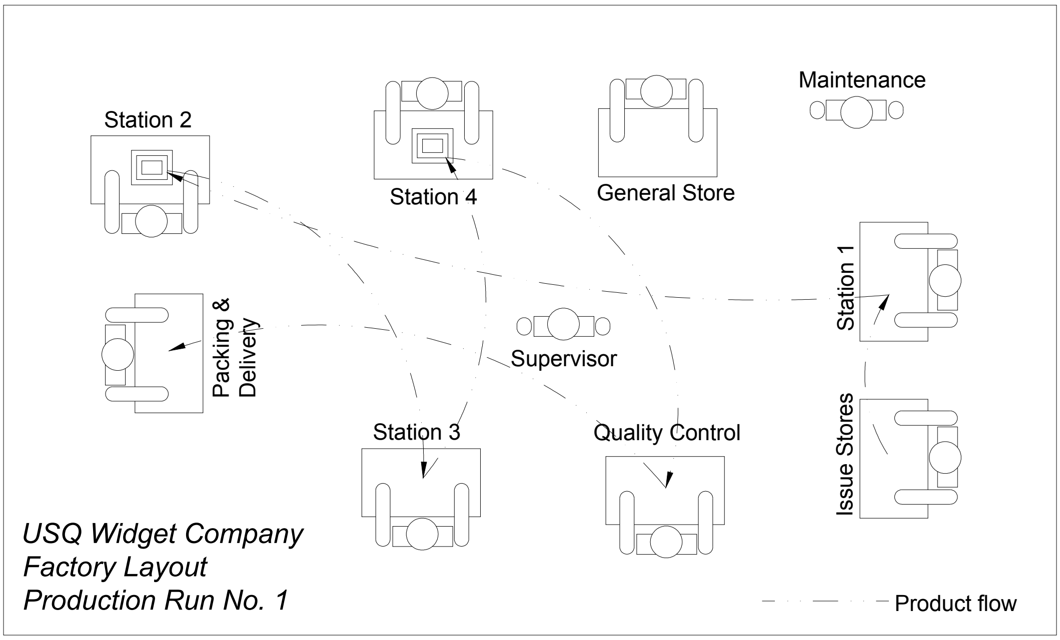

Figure 1 : Diagram illustrating the layout of the work stations for the 1st production run

Developing Team and Problem-Solving Skills

At the end of the 1st production run, the students were allocated into "production consultant" teams. The facilitator then provides some guidelines as to what constitutes a "good" team (Meredith, 1993).

The facilitator further discussed the different problem solving techniques that can be used to analyse problems and develop solutions. These included:

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

The students were then provided with a brain-storming worksheet which specified six steps to be followed. These were:-

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 (Edwards et al., 2004). This step requires the student to answer the "5W's + H" questions (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.

Working in their teams, students were required to provide reasons for the poor output in the 1st production run, and ways in which the assembly process could be improved to meet the production target. Note that the facilitator had not provided any reasons why the 1st production run failed to meet the target. This encouraged the team to engage in open discussion and exploration of ideas.

Following this team involvement, the team leaders presented their team's findings and suggestions. The presentation also provided for enhancing verbal presentation skills. During this open discussion, the teams compared notes and devised a plan of action to improve the assembly process. The facilitator listed all the problems on the board, together with the suggested solutions. The groups then decided on the most appropriate course of action to be implemented. This process easily identified the constraint or bottle-neck in the process. The teams were instructed to direct maximum effort and resources to reduce or eliminate this constraint. After agreeing on the actions needed, the group undertook the next production run.

The 2nd Production Run

In this production run the manager (facilitator) was more open to worker (student) input and allowed the students to have control over the work environment, and implement their ideas for a more efficient run. Prior to the start of this run, the facilitator prompted further discussion as to what can be measured to quantify the assembly process. Students decided to measure the time for assembling a single unit, which they would use to benchmark this process. Also measured were times lost in machine breakdowns and machine maintenance. At the conclusion of this run, the students produced only 8 batches.

The students were once again required to work within their teams to identify other constraints and explore any further improvements that could be undertaken. At this stage of the game, the improvements related to more complex manufacturing theory and World Class Manufacturing Techniques. The facilitator provided more cues to focus the students' attention along these lines.

The Final Production Run

The students now implemented their ideas and conducted the final production run (Refer to Fig. 2 and Fig 3). The important techniques implemented in this run were:- efficient factory layout for better product flow; quality control is every workers responsibility; introduction of kanban to provide for a "pull" production process (just-in-time manufacture); ergonomic considerations for better machine operation; preventative maintenance and the "visual" factory. In every workshop conducted, all groups achieved the target output within the allocated time. It must be noted that the improvements implemented to the assembly process were the students' ideas and initiatives, supplemented with cues from the facilitator.

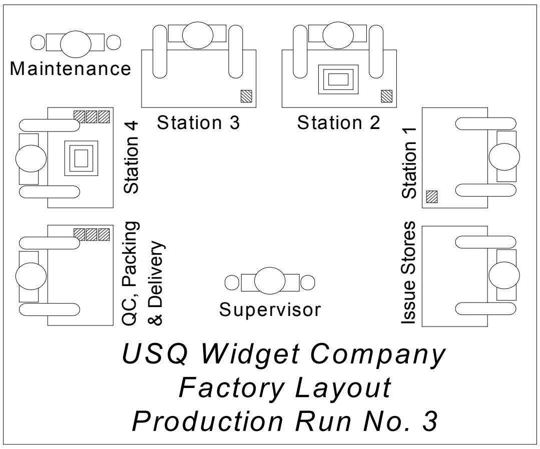

Figure 2: Layout incorporating World Class Manufacturing Techniques of efficient product flow, Just-in-time(kanban) system and elimination of "waste".

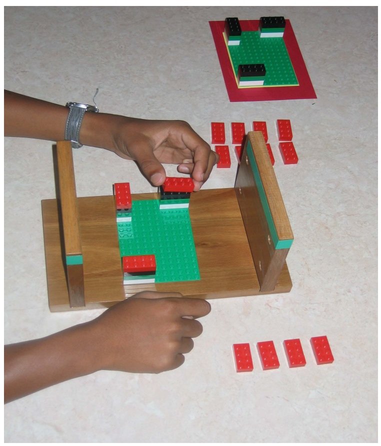

Figure 3: Photograph of Station 4 showing the wooden jig which represents a machine. Note also the kanban card (top right of picture) which controls the flow of the products

Assessment of Student Learning and Experiences

This simulation game was run over the last few years as an on-campus activity in the course "Manufacturing Processes", and as a trial at a few local high-schools. Approximately 120 students were surveyed. The learning outcomes of this simulation game were assessed with the aid of a simple questionnaire. There were two aspects to the evaluation:-

(i) an assessment of the increase in understanding and application of manufacturing theory, team dynamics and problem solving skills. The students were asked at the beginning of the workshop to rate their understanding of the World Class Manufacturing techniques (waste reduction, 5S's, material flow, Just-in-time manufacture, reduction of set-up time, and theory of constraints). The students were then asked at the end of the simulation game to again rate their understanding of the concepts. The graph below (Fig. 4) illustrates that the students' perceptions of the manufacturing concepts has more than doubled. Observation of team dynamics and problem-solving skills also show a similar trend. Future investigations into the impact that this game has on student understanding is being developed. This will include an analysis of examination results and possibly a survey of graduates who may have implemented these techniques in their workplace.

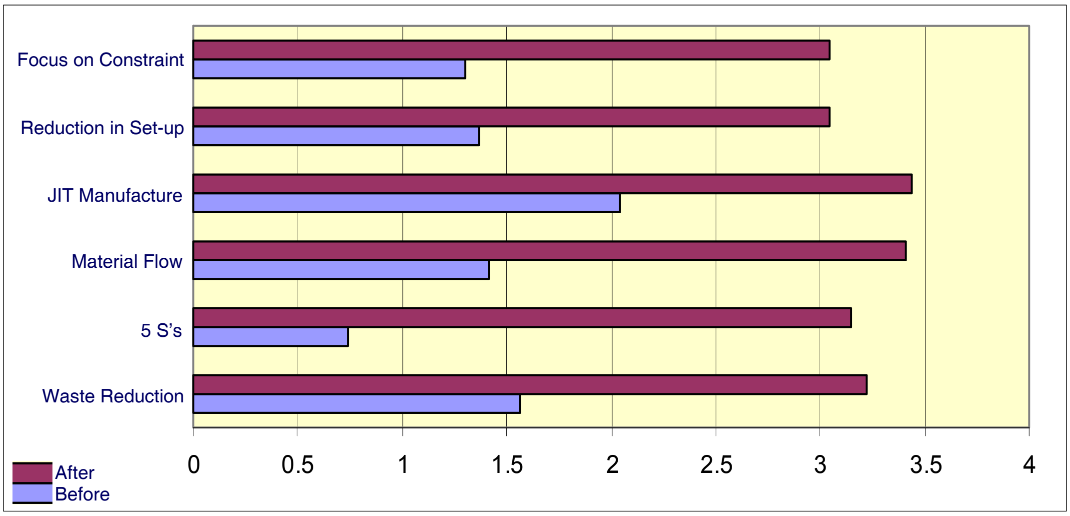

Figure 4: Graph illustrating the increase in perceptions of the Manufacturing concepts

(ii) an open- ended response to aspects of the learning and facilitation of the workshop. Below are some of the students comments:-

"Reinforced knowledge through hands-on activity"

"Very visual in describing how these ideas work"

"Interactive learning environment"

"The ability to see the benefit of system refinement"

"Fun way of learning. It was hands on."

"I am a kinesthetic learner, and this game was great."

"Actually trying ideas, not just talking about it."

"Hands on, made it enjoyable to learn and easier to understand."

Discussion

At the final de-briefing and reflection session, the students unanimously stated that they have a greater understanding of the manufacturing concepts, team dynamics and are more motivated and confident about using the various problem solving techniques. A common response was that they "theoretically" knew about these concepts but only appreciated their impact once they employed them in a "real" situation. Their formal and informal feedback reflect their improved understanding of the concepts, especially the push-pull methods of manufacture and kanban practice; a concept that is difficult to understand by reading the theory. The learning and understanding of this theory is best undertaken by "doing". This simulation game is an excellent tool to enhance the teaching of this and similar course content.

Conclusion

There are many topics in engineering courses that are difficult to teach; especially if the concepts involve complex large scale-systems. Manufacturing theory is one such topic, where good understanding is dependent on the application of the theory. In this context, simulation games are ideally suited to demonstrate and increase understanding of the theory. A manufacturing simulation game, based on a QMI industry-based workshop on World Class Manufacturing techniques, has been used to enhance the teaching on "Manufacturing Processes". Student feedback reflect a great improvement in their understanding of the theory; in particular just-in-time manufacture, push-pull production and waste reduction. The game also enhances team interaction and problem-solving techniques.

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