AC 2007-152: ENHANCING STUDENT LEARNING IN ENGINEERING TECHNOLOGY PROGRAMS ? A CASE FOR PHYSICAL SIMULATIONS

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Enhancing Student Learning in Engineering Technology Programs – A Case for Physical Simulations

Abstract

Physical simulations have a proven record as a teaching tool. Concepts that are often hard to grasp are made easy by the use of physical simulation activities. The constructivism learning theory suggests that people learn better by actively participating in the process of learning. According to the Encyclopedia of Educational Technology, "Simulation-based learning involves the placement of a student into a realistic scenario or situation. The student is then responsible for any changes that occur as a result of their decisions."

A number of physical simulation based tools have been developed by the author for use as instructional tools to enhance student learning. A description of each of these tools is provided along with their implementation in the class-room environment. A number of these tools were pilot tested in the computer integrated manufacturing course in the mechanical engineering technology program. Student evaluations indicate a marked increase in learning and comprehension of manufacturing concepts.

I. Introduction

Organizational change to enhance productivity is a topic of interest to many organizations seeking to improve global competitiveness. Organizational change often involves change in culture of the employees and how they view their work. Many productivity enhancement philosophies like Lean and Six Sigma emphasize the importance of cultural change as a prerequisite for sustaining the improvements made as a result of these philosophies. Retention of knowledge is often a function of how well the concepts are understood. This is where the physical simulations have their greatest impact as a learning and productivity enhancement tool.

Major mass and batch producers in the United States have adopted Lean and Six Sigma philosophies to minimize waste and improve operational efficiency[1]. A number of these organizations have failed in implementing these philosophies[2, 3 & 8]. This is primarily due to lack of sufficient number of trained employees to reach a critical mass for organizational transformation. Training all employees in the principles of Lean and Six Sigma is a critical part of the organizational transformation process. Higher education has also lagged behind in incorporating Lean and Six Sigma philosophies into the educational curriculum. A limited number of universities are offering graduate and undergraduate courses in Lean manufacturing. An initial survey of higher education indicated that only ten universities had a course in lean manufacturing and out of these only three were using physical simulation as a tool for teaching Lean.

This paper discusses the implementation of five simulation tools in a senior elective within the MET program to teach students about Lean and Six Sigma philosophies and their implementation.

II. Research on Understanding and Learning

Ancient Chinese philosopher Confucius once said *"I see and I forget, I hear and I remember, I do and I understand."* We all know this instinctively, however, turn-of-the-century educationist Edgar Dale illustrated this with his *Cone of Learning* as illustrated in Figure 1. He made an observation that "*After two weeks we remember only 10% of what we read, but we remember 90% of what we do!.*" Existing literature on understanding and learning also points to the fact that learning and retention are enhanced by activities involving actual work within a simulated work environment. Gardner [6] mentioned that *"Understanding is a result of the learner reshaping and transforming information."* Savery and Duffy [7] concluded that *"One's knowledge is refined through negotiations with others and evaluation of individual understanding."*

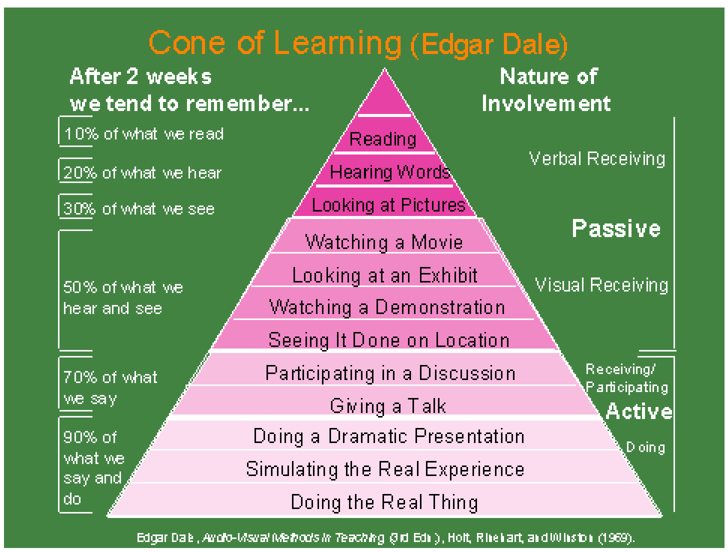

Figure-1, Cone of Learning by Edgar Dale

III. Various Learning Paradigms

Various learning paradigms have emerged in our quest for enhancing student learning and comprehension. Common terms used while describing these paradigms are: case studies, project based learning, interactive learning, active learning, e-learning, role playing, gaming, computer simulations etc. While some of these are synonymous, others are quite different. These paradigms can be broadly classified into three categories; Case Studies, Project Based Learning and Simulation Based Learning, as shown below in Figure 2.

Figure-2, Various Learning Paradigms

Simulation based learning can be of two types, computer based simulation and physical simulations. Computer based simulations take the form of animations, discrete event simulations and continuous process simulations. On the other hand, physical simulations combine aspects of role playing and project based learning. This concept is illustrated in Figure 3 below.

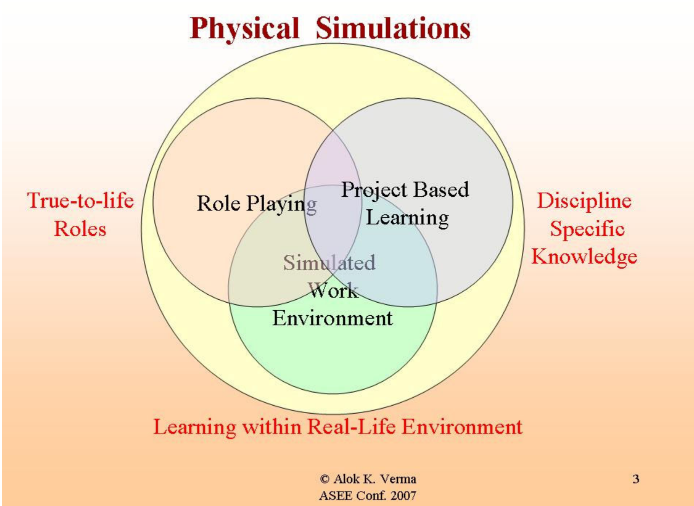

Figure-3, Physical Simulations

IV. Physical Simulation as a Teaching Tool

Physical simulations have a proven record as a teaching tool. Concepts often hard to grasp are made easy by the use of simulation activities. The constructivism learning theory suggests that people learn better by actively participating in the process of learning. In order to involve students into the participatory learning process, the interaction among students, between students and the instructor in a classroom setting becomes very critical. According to the Encyclopedia of Educational Technology[6], "Simulation-based learning involves the placement of a student into a realistic scenario or situation. The student is then responsible for any changes that occur as a result of their decisions."

Educators have been designing, using, evaluating and writing about simulations for more than 45 years. However there are no generally accepted definitions of an education simulation or its many variations. Education simulations are sequential decision-making classroom events in which students fulfill assigned roles to manage discipline-specific tasks within an environment that models reality according to guidelines provided by the instructor. Education simulations typically place students in true-to-life roles, and although the simulation activities are "real world," modifications occur for learning purposes[11].

Another important use of simulations in education is to facilitate efforts at what has become known as "bridging the gap" between academics of profession and practice of that profession. Simulations are ideal for connecting factual knowledge, principles, and skills to their application within a profession. Simulations help students with an opportunity for decision making, and for evaluating the consequences of their decisions that no textbook or laboratory can.[12].

Simulations weave substance-specific information into real life problems in meaningful ways that students can understand. During simulations, students typically acquire broad discipline-specific knowledge that they are able to later transfer into a professional setting. Simulations also teach much more, including the process involved in the discipline, the organization involved, and the interactions with other discipline, people, and organizations. David Jennings[9] examined the use of three learning methods in the teaching of strategic management; the case method, simulation and action learning (in the form of a consultancy project). The results indicated that simulation is the most effective method.

V. Incorporating Physical Simulation within the MET Program

Lean and Six Sigma material has been incorporated into the MET curriculum via a senior elective titled Computer Integrated Manufacturing. Approximately 30% of course deals with Lean and Six Sigma philosophies. The course starts with lectures on Lean and Six Sigma principles followed by simulation activity. The goal of this course is to provide the students with competency-based, hands-on learning that supports a systems approach about Lean and Six Sigma philosophies and their implementation. Prerequisites for the course include general knowledge about manufacturing systems and sophomore level course in materials processes and manufacturing. Student responses have been collected and evaluated via an attitudinal survey. Student comments indicate positive response towards the course content and simulation activity.

VI. Attitudinal Survey to Assess Impact of Lean Training

The challenge of organizational transformation is in changing how people feel about their day-to-day job. Application of Lean and Six Sigma tools and techniques are relatively simple compared to changing the work culture and attitudes. Thus, it is important to assess the change in the attitude of people.

An attitudinal survey was created to assess the impact of training on the thinking of students. The attitudinal survey assesses how a student's thinking about Lean manufacturing and Six Sigma have changed during the training on a scale of 1-5. A score is generated from the survey from pre and post testing. The difference in the score represents the change in the attitude of students. Thus, a larger difference represents higher impact of training program on student's thinking. In the following sections, a short description about each of the three simulation activities is given.

VII. Value Stream Mapping Simulation

This simulation activity has been developed in the form of a board game to explain the concepts of Value Stream Mapping (VSM) and analysis. This simulation explains the basic concepts of Value Stream Mapping, drawing of the Current state map, development of Future state map, and implementation of the future state.

Simulation activity is run in three phases and the results of implementing various lean tools are observed. Effects of various tools like the Supermarket, Kanban, and Pull system are observed in a learn-by-doing environment. This simulation activity can be used to compliment existing training programs in Lean manufacturing. Results obtained during pilot sessions show a reduction in lead-time of almost 50% by reducing the non-value added time. The ratio of non-value added time to value added time goes down from 32.96 to 15.46. Figure 4 shows the board used to conduct the current state simulation.

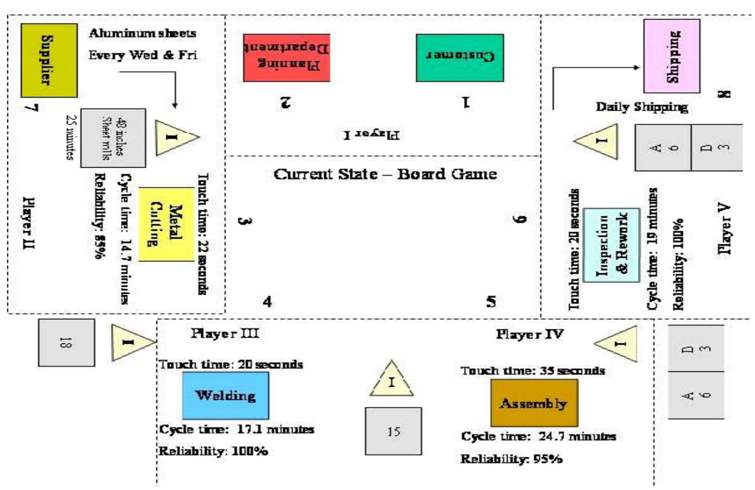

Figure-4, Value Stream Mapping Simulation Board

VIII. Setup Reduction Simulation

The setup reduction simulation uses the production of parts using a die block as a background for implementing Lean tools and techniques. This simulation is also carried out in three phases. First phase uses the traditional production techniques resulting in large defects and long times for setup change. During phase two and three, various Lean tools like 5S, Point of Use Storage etc. are applied to reduce the changeover time.

IX. Block Tower Simulation

This simulation uses Lego blocks for constructing three types of towers with alternating color blocks. The activity involves team work and use of Lean tools to achieve higher production rates by encouraging participants to break the assembly into common sub-assemblies. Figure 5 shows the three models of block towers constructed during simulation.

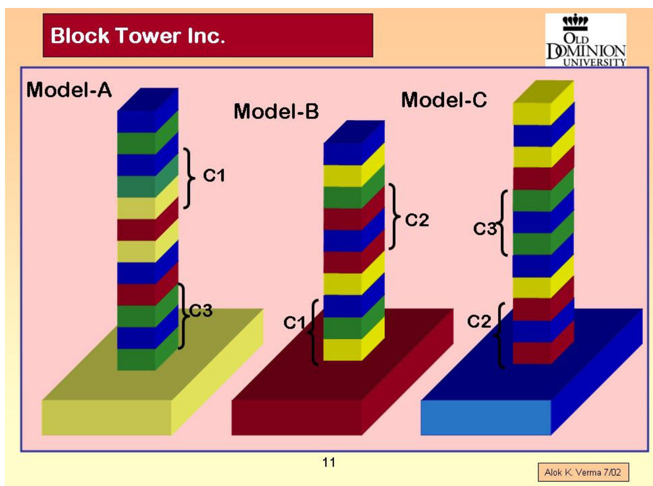

Figure-5, Block Tower Simulation

Fourteen to twenty people can participate in these simulation activities. During simulation participants are assigned to different departments and these assignments are rotated between phases to remove the bias due to job familiarity.

X. Results

Results from the attitudinal survey are shown in Figure 6 as histogram of student responses from the pre and post training evaluations. The x axis represents the scale 1-5 on which respondents evaluated questions on the attitudinal survey, 1 being strongly agree and 5 being strongly disagree. The student responses were fitted to a polynomial and the value of mean is indicated by a dashed line. Figure 6 clearly indicates that the post training response curve is skewed to the right. Before the simulation training, mean of student responses was 3.31 and after the simulation activity this mean moved up to

3.73. This indicates that the class room training utilizing physical simulations had an impact on the learning and retention of the participants.

XI. Conclusions

This study shows that, student learning and retention of important manufacturing concepts are made easier by incorporating physical simulations within the course material. Student learning is also enhanced by including examples of actual Lean and Six Sigma implementation from various industries. Physical simulation activities provide understanding of the concepts and first hand verification of the advantages of Lean and Six Sigma.

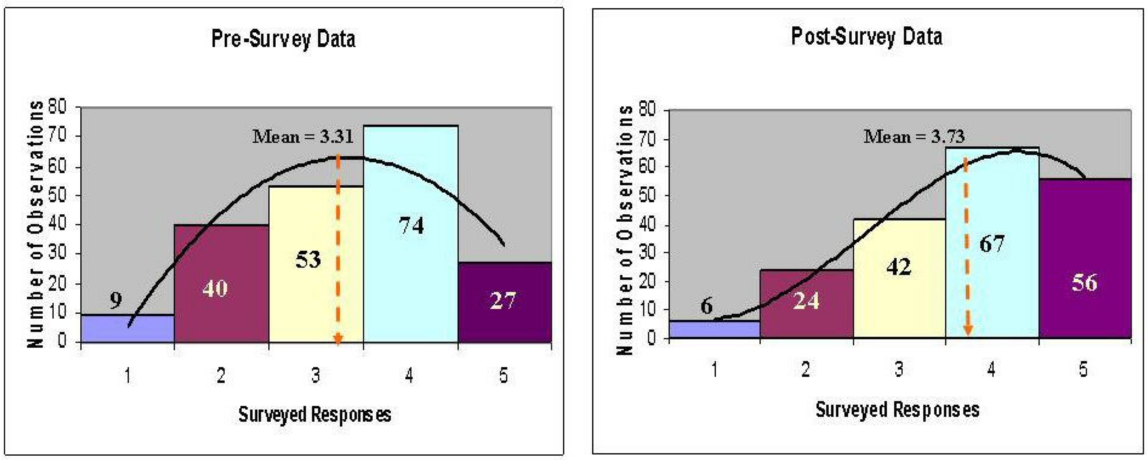

Figure-6, Plot of Student Responses

Incorporation of physical simulations into a senior elective creates a course that is both engaging and educational for students. The primary goal for making this change is to ensure that students are familiar with the powerful philosophies for organizational transformation before stepping out into real world. Comparison between pre and post attitudinal survey results indicate statistically significant improvement in students understanding of Lean concepts and tools.

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