ABSTRACT

This article evaluates the learning outcomes from a lean classroom exercise. Teams produce a product consisting of a half-sheet of paper with colored dot stickers attached in specific locations. The results of the game are consistent with students gaining a better understanding of the principles of lean at the conclusion.

INTRODUCTION

“Tell me and I forget, teach me and I may remember, involve me and I learn.”
– Benjamin Franklin

For many business students, the concepts of lean are foreign. Many times students do not have a basic understanding for the application in the manufacturing world. Additionally, students have difficulty relating manufacturing concepts to service industries. There are many times when a principle being taught is better understood by a classroom activity. For example, the “Beer Distribution Game” developed by the System Dynamics Group at MIT, consistently demonstrates principles of systems dynamics and supply chain behavior (Sterman, 2001).

The Spot Dot Game provides similar benefits while teaching the principles of lean. The game was introduced to us by Mike Collins, a vice president for lean operations at a Salt Lake City production company. Over the years we have collected data on the game that demonstrates its consistency in providing learning outcomes for the students. In this paper we will discuss the value of educational games, clarify the value of lean understanding, briefly explain the game and then examine the learning outcomes that consistently demonstrate the principles of lean to the students.

THE VALUE OF GAMES FOR LEAN

In a study of undergraduate students, Elbadawi et al. demonstrated that by using a paper plane simulation game to teach lean manufacturing concepts, student knowledge increased significantly compared to a lecture-based alternative (Elbadawi et al, 2010). Badurdeen et al evaluate the use of simulations and games to teach lean principles and conclude that the use of hands-on activities prior to the introduction of lean concepts is consistent with the teachings of lean and the Toyota Production System (Badurdeen et al, 2010). Games to demonstrate lean concepts are also touted in industry (Rowlands, 2005).
HOW TO PLAY THE GAME

Game Requirements

To play the game, approximately 60-90 minutes of time is needed; the time varies depending on the number of teams as well as the level of discussion after each round. For each team, a stapler, 100 sheets of paper (which will be cut into 200 half-sheets), and approximately 50 sheets of ¾” dots are needed; the number of sheets per dot color is proportional to the number of dots (1, 2, or 3) of that color used by the team. Technically, if no waste is created, a team can produce all three rounds of their product with 60 sheets of paper and approximately 30 sheets of dots, but it is unlikely that waste is not created in the first round and possibly other rounds. Each team also has instructions for each assignment as well as a quality measurement sheet to track scrap and rework. In addition, a timer (an online timer works nicely) and a way to post the team results – a white board, computer projection, or large paper pad – are needed.

Team Role Assignments

Students are assigned to a team and one of the following roles in the game (shown as needed per team):

(1) Shipping/Receiving/Stock (1 person): Responsible for maintaining raw materials (paper templates, sheets of dots, stapler), delivering raw materials to production operators, and delivering finished goods to customer.
(2) Production Operators (5 people): Responsible for production based on assigned material and skills.
(3) Inspector (1 person): Responsible for inspecting work and keeping track of rework, scrap, and customer returns.
(4) Customer (1-2 people): Responsible for checking and accepting delivered orders.
(5) Observers (numerous): Responsible for observing the process.

Ideally, we try to create as many ‘teams’ as we can to limit the number of ‘observers’ in the game. The students are told they are members of The Spot Dot Company which produces a product that consists of a half sheet of paper with a series of ¾” dot stickers placed inside a 7/8” circle to a specified area in a given color. Examples of an empty (left) and a completed (right) sheet are shown in Figure 1.

FIGURE 1: DOT SHEET EXAMPLES
The basic flow process for Round 1 is shown in Figure 2. In Rounds 2 & 3, the process flow may change depending on decisions made by the workers, so there are a variety of possible flows. What is not clearly shown in Figure 2 is that people are located all over the room, so the flow is quite choppy as people must deliver from one station to the next. In Rounds 2 & 3, the teams typically choose to locate together and work in a linear or cellular format. Below are the descriptions of what happens in each round. In Table 3, the parameters of the game are compared across rounds.

**FIGURE 2: FLOW CHART OF ROUND 1 PROCESS**

**Round 1**

In Round 1 the students are told that they must remain in their current location. The stock person staples four sheets together and carries the sheet packet to the first production worker (assigned to the color in the first column of the sheet). That production worker places the stickers for his/her color on each of the four sheets of the packet and then carries the sheet to the next production worker (whose color is represented in the second column of dots). The packet continues through the process until the fifth production worker completes his/her column of dots and then carries the packet to the inspector. The inspector checks the packet and either returns it to be reworked (to any stations needing to correct the work), scraps items that are not repairable (and initiates a replacement set of sheet(s) to be produced), or approves it for delivery to the customer and returns the packet to the stock person. An example of a rework would be a dot that is not fully pressed down or is missing and an example of a scrap would be a dot that is touching the outer circle.

Once an approved packet of sheets is given to the stock person, the stock person delivers the packet to the customer. In addition, the stock person must hand out sheets of dot stickers to the production operators when they run out of stickers (i.e., the sheet of stickers is completely empty); the production workers must come to the stock person’s station and wait until he/she is there to receive a new sheet of stickers.
The round is run for a month which is designated by 10 minutes’ time (2.5 minutes/week). Each round the customer requests 40 sheets (or 10 packets of 4 sheets) with an on-time delivery of one packet per minute during the 10-minute ‘month.’ At the end of the month, statistics are gathered for each team. All work-in-process (WIP) is removed at the end of the round. The statistics gathered are shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1: STATISTICS GATHERED IN EACH ROUND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to complete first order</td>
</tr>
<tr>
<td># of reworks (sheets)</td>
</tr>
<tr>
<td># of scrap (sheets)</td>
</tr>
<tr>
<td>Customer returns (sheets)</td>
</tr>
<tr>
<td>WIP at end of 10 minutes</td>
</tr>
<tr>
<td># of sheets produced (total – scrap)</td>
</tr>
<tr>
<td>Productivity = ( \frac{\text{sheets produced}}{\text{time in seconds}} \times # \text{ of people} )</td>
</tr>
<tr>
<td>Percent delivered on time</td>
</tr>
</tbody>
</table>

Round 2

In Round 2, the students are told that they may redesign their team’s layout, but they must maintain the same ‘skill’ they had in the previous round (e.g., those who are putting on red stickers only have the ‘skill’ for red stickers and cannot assist someone with blue stickers). The production operators are asked to inspect their own work and put the order out for the inspector if there is rework or scrap (rather than passing it on in the process).

Now, the production operators may have two sheets of dot stickers, one they are currently using and one as a backup. When they complete one sheet of stickers and begin using the next, they may inform the stock person that they need another sheet of stickers and the stock person will deliver it to them. The inspector may now move around to work stations picking up any rework or scrap. The round is run for the same 10-minute ‘month’ and the same statistics are collected at the end of the round and all WIP is removed after it has been recorded.

Round 3

In Round 3, the students are told that work will now be completed in single sheets (no longer batched into 4-sheet packets). Kanban squares (large index cards) are added between processes such that each kanban square may hold a single sheet waiting to be processed (with the exception of shipping which may hold up to six sheets in its kanban space). Production operators are told to stop production if the kanban in their downstream production is full. The team can decide if they wish to keep the same number of workers and/or if they wish to cross-train workers.

To represent changeovers from one process to the next, workers must count to two before beginning a different ‘skill’ and then must count to two again if they are switching back to the original ‘skill.’ Everyone is asked to not only inspect their own work, but also validate the work from the previous station. The ability to have two sheets of dots and receive a new delivered sheet when the first sheet is completed is still in effect. The delivery schedule for the customer is still 40 sheets in the month, but it is not evenly distributed. The customer’s new demand schedule
is listed in Table 2. To better represent that customer demand is not equally distributed throughout a month, during Round 3 we maintain the total demand of 40 sheets but vary the demand to demonstrate that production can accommodate demand variations and react to larger or smaller orders as needed.

A comparison of the parameters from each round is listed in Table 3.

### TABLE 2: ROUND 3 CUSTOMER DEMAND SCHEDULE

<table>
<thead>
<tr>
<th>Minute</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Sheets</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Cumulative Sheets</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>18</td>
<td>19</td>
<td>23</td>
<td>25</td>
<td>31</td>
<td>34</td>
<td>40</td>
</tr>
</tbody>
</table>

### TABLE 3: GAME PARAMETERS BY ROUND

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ROUND 1</th>
<th>ROUND 2</th>
<th>ROUND 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Packet Size</td>
<td>4 sheets</td>
<td>4 sheets</td>
<td>1 sheet</td>
</tr>
<tr>
<td>2. Staple</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3. Dot sheets allowed at station</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4. Dot sheet replacement</td>
<td>Retrieve from stock person when he/she is available</td>
<td>Delivered by stock person once 1st sheet is depleted</td>
<td>Delivered by stock person once 1st sheet is depleted</td>
</tr>
<tr>
<td>5. Quality Inspection</td>
<td>Inspector checks finished product</td>
<td>Production Operators check their own work Inspector checks finished product</td>
<td>Production Operators check their own work and any preceding work completed on the sheet Inspector role may or may not exist based on roles assigned</td>
</tr>
<tr>
<td>6. Customer Demand</td>
<td>1 packet (4 sheets) each 10 minutes for a total of 10 packets (40 sheets)</td>
<td>1 packet (4 sheets) each 10 minutes for a total of 10 packets (40 sheets)</td>
<td>Individual sheets (no stapling) delivered according to specified demand schedule for a total of 40 sheets (Table 2)</td>
</tr>
<tr>
<td>7. Cross-Training</td>
<td>Not allowed</td>
<td>Not allowed</td>
<td>Workers must count aloud to two if switching between ‘skills’</td>
</tr>
<tr>
<td>8. Kanban Squares</td>
<td>None</td>
<td>None</td>
<td>Only one sheet allowed between stations with the exception of shipping which can have up to six</td>
</tr>
</tbody>
</table>
GAME ANALYSIS

Data Collection

Based on 25 sessions with 72 teams playing the Spot Dot Game, data was collected based on the statistics mentioned in Table 1. Depending on the size of the class, there were anywhere from one to four teams during a given occurrence of the game. All teams were told that they work for the same company, but each team is assigned to a different product line. The product lines were differentiated by having different order and selection of dot colors as well as a different color for the paper on which the dot stickers are placed. As the number of teams increases, so does the potential chaos (especially in Round 1) and the inevitable competition for meeting production goals.

The game was played during the second class period in a graduate-level operations course. Although some MBA student may have prior knowledge of lean principles, the students were not asked to prepare for the activity by completing any readings ahead of time as it is best for the ideas for improvement to come organically during the game. After playing the game, students were asked to participate in an online discussion in the week following the exercise. Students are asked to have read two Harvard Business Review articles after the game: “Learning to Lead at Toyota” and “The Lean Service Machine” (Spear, 2003; Swank, 2004). Students are asked the following four questions:

1) Improvements from Round #1 to Round #2: What do you think contributed the most to improvements during Round #2?
2) Improvements from Round #2 to Round #3: What do you think contributed the most to improvements during Round #3?
3) Takeaways: Amidst the chaos from the early part of the game, there were clearly process improvements of many different types that occurred during the game. There are a number of takeaways that you can have observing what happened in the game. Read over the other responses. Then, please share your insight or build on someone else's insight if it is similar to what you were going to say.
4) Lean Readings: What concepts/learning from the lean readings can you relate to the game?

Quantitative Results

Upon examination of the sheets produced from round to round, it was found that teams consistently improved their ability to deliver the finished goods in each successive round. In Figure 3: Sheet Production by Round, the majority of teams in Round 1, 51%, delivered between 16-20 sheets, just half of what was requested by the customer. By Round 3, 96% of the teams delivered 90-100% of the customer demand (36-40 sheets) compared to only 44% that did in Round 2. In Round 3, 91.7% of the teams delivered the full order of 40 sheets whereas only 19.4% accomplished the task in Round 2. Similarly, the productivity of each team consistently increased from round to round.
As the rounds increase, the time to complete the first order decreases as shown in Figure 4. From Round 1 to Round 2, the average percent reduction in time to complete first order is 28% from Round 1 to 2 and 56% from Round 2 to Round 3.

In addition to completing the first order faster each round, the percentage of on-time deliveries increases as the rounds progress as shown in Figure 5.
Interestingly, the quality of the output, based on rework, scrap, and returns, decreases from Round 1 to Round 2 but improves in Round 3. This counterintuitive result may be a result of either the facilitator not stressing the importance of quality or the fact that when teams are focusing on meeting demand, there is no penalty in the productivity measurement for bad quality. Typically, the production workers are unaware that some adjustment in their process has created problems with quality. For example, it is common that production workers take their dots off of their sheets while waiting for the next order to arrive. Sometimes, the stickers get a crease or are less sticky and have trouble being fully pressed down (a quality issue which could result in a customer return). Figure 6 shows the average amount of rework, scrap, and customer returns (represented by the average numbers of sheets of product where each sheet represents 2.5% of the total order).
Qualitative Results

Currently we are evaluating the qualitative results by studying the discussion postings of students after the game is completed. We hope to have a full report of the qualitative results at the Decision Sciences 2013 meeting.

Implications on Learning Outcomes

Based on the quantitative findings, it is clear that students see progress in their production efficiency from round to round. Students recognize the importance of balancing job loads, cross-training, and locating near one another in a cellular layout. By actively engaging in the process, students more clearly understand the concepts of lean improvements. After looking at the quality results, it is clear that the measurements collected may not be of concern to the students if the end result is to deliver products as needed and on time. It is likely that either focusing on reducing customer returns or penalizing a value on which the team is evaluated every time quality problems occur, different behaviors may result. Given the real-world cost of customer returns (external failures) versus scrap and rework (internal failures), the measure should penalize more heavily for external failures. It is also possible for the facilitator to make it clear to the company workers that customer returns are unacceptable in the workplace.

CONCLUSION

Overall the Spot Dot Company simulation game is well received by students. It is an exercise that translates to people of all different backgrounds as the process can feel like a production of a product or the completion of a service. After completing the game, it allows students to read articles on lean concepts with a better understanding of what lean improvements to a production system mean. We look forward to further supporting our claims by thoroughly analyzing the qualitative results from the students.

REFERENCES


