Session #: 1557

# Activity Based Learning - Wagons R Us – A Lean Manufacturing Simulation

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## Abstract

There is no substitute for experience. As educators, we cannot teach our students "experience". However, are able to provide an environment that simulates real world problems and fosters creative thinking and the development of possible solutions. Activity based learning is built upon this premise. Active learning is explained by Bonwell and Eison as, the students "are doing things and thinking about what they are doing".[1]

To accomplish this, a group of Engineering Technology students were challenged to apply the lean manufacturing concepts learned in class to a pre-designed production simulation. The simulation, "Wagons R Us", required the students to assemble wagons using K'NEX plastic components as their raw materials.

The simulation begins by having students participate in and observe an extreme case of a traditional production system. According to Dr. Ann Stalheim-Smith, "active learning is not a spectator sport".[2] Therefore, the exercise required each student to actively participate. Students were divided into teams, given the constraints of the system and had one week to implement a more efficient lean manufacturing system. Student teams had to identify the different types of waste associated with the existing simulation and redesign the process to eliminate non-value added activity throughout the process.

During the competition, each team would simulate production for thirty minutes. In some cases, the students had to renegotiate their union contract to facilitate improvements made to the manufacturing process. The team that produced the highest number of good wagons with the least amount of labor would be the winner. Points were awarded for the teams that produced the most quality products in the most efficient manner. The students witnessed first hand the importance of lean manufacturing, waste identification and elimination and teamwork in a successful manufacturing system.

## I. Introduction

The "Wagons -R- Us Project" is a production project that allows students to simulate an assembly production environment. The original simulation was developed by Tom Carlisle, a professor at Sinclair Community College, Dayton, Ohio. The process is simulated using a product developed by K'NEX Industries, Inc. Their mission states, that "K'NEX offers exceptional play value through building and bringing models to life. It inspires creativity, builds self-confidence and encourages interaction among children and parents. The possibilities are endless!" [3] Now, the University of Dayton is using K'NEX to teach some principles of production in their Production Management Methods course (IET 308). Students get to see and participate in a push production system. Then, they get an opportunity to develop a better production method by utilizing and integrating lean manufacturing techniques they have learned in the classroom setting.

## II. Background

In order to simulate an assembly production environment, a product needs to be produced. For this project, wagons were assembled using various K'NEX parts. The wagon type that was assembled for this project is shown in Figure 1.0.

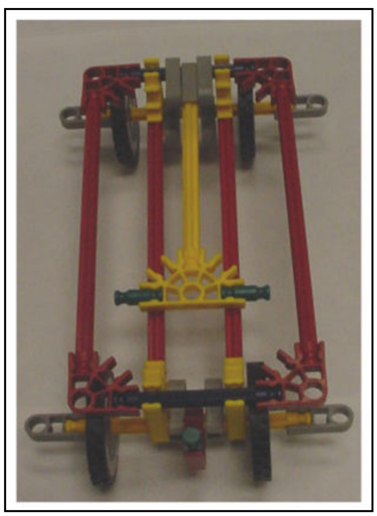


**FIGURE 1.0**
ASSEMBLED WAGON

The simulations were conducted at Sinclair Community College. Each student received a project document for review the week before the initial simulation. The documents were titled, "Wagons –R-Us Simulation #1 Material Movement, Job Assignments and Priority Rules". Some of the students participated in the initial simulation conducted by the instructor, while others took measurements of the layout. The remainder of the students observed and took notes. The initial simulation was designed to reflect the worst case scenario.

## III. Description

This project was designed to help students recognize and understand how important production control is to a production process. Production control systems, whether in manufacturing process or product assembly, ensure that products are produced in the required quantities, at the right times and at the highest level of quality. Typically, a manufacturing or assembly process involves coordinating numerous stages so that materials produced or sub-components assembled at some stage arrive in the right quantities and at the right times at other stages that need them.

The traditional form of mass production is called the push production system. With this system, the schedule is based upon when the order is expected to arrive at an operation, plus the time when the operation is expected to complete any pre-existing jobs and be available. As a job order moves from operation to operation, work is performed in batches where the size of the production batch is the same as the customer order, which this was the case for the initial simulation.

In a pull production system, the consumer initiates production by withdrawing whatever is needed from stock. When this happens it begins a chain reaction back through the production process and when the amount in stock reaches some minimum level, it signals the producer at the upstream location to replenish the removed stock. The producer or assembler then makes, assembles, or procures the material in some pre-specified quantity and puts it into stock. This approach will be discussed later in the observations of each team's simulation.

## IV. Purpose

Based on what has been taught in the classroom setting about the advantages and disadvantages of different production systems, this project provides an opportunity for students to see first hand the benefits or deficiencies of one system over another. Also, the student observes what works and what does not work for a typical production environment. Students quickly learn that just because something doesn't work well in one environment, doesn't mean it will not necessarily work in a different environment. Knowing what to look for and being able to identify the different systems in place is important. But even more important is understanding how to change the system for the better to make both the person and the company successful. The goal for each team is to improve the process and run a simulation with their proposed improvements. The team who can improve the process and create the greatest amount of good parts in a given time period is declared the winner.

## V. Initial Simulation Description

The scripted simulation was a classic push production system. This simulation required eleven people to be involved in the wagon production system. Seven union workers consisted of six production operators and one an inspection operator. The other four workers were salaried, nonunion employees who provided no value to the product. The schedule was based on when an order was received from the customer. Once the order was received and a routing sheet filled out, it was then carried by the production shop foreman (nonunion) to the material movement operator (MMO). The MMO would then gather up all the required raw materials to fill the order and deliver the materials to the first operation. Also, the MMO was responsible for moving parts and materials from one operation to the next for five operations.

The routing sheet stated how many wagons were to be produced. As the product moved through production, information such as when they received the order, started working on the order, and completed the order was recorded on the router. The production layout and the path the material moved throughout the process are shown in Figure 2.0. Notice the path that the MMO had to take to move the orders in their various stages through the facility and the fact that the MMO returned to the raw material storage after each move to continue preparing orders received from the customers.

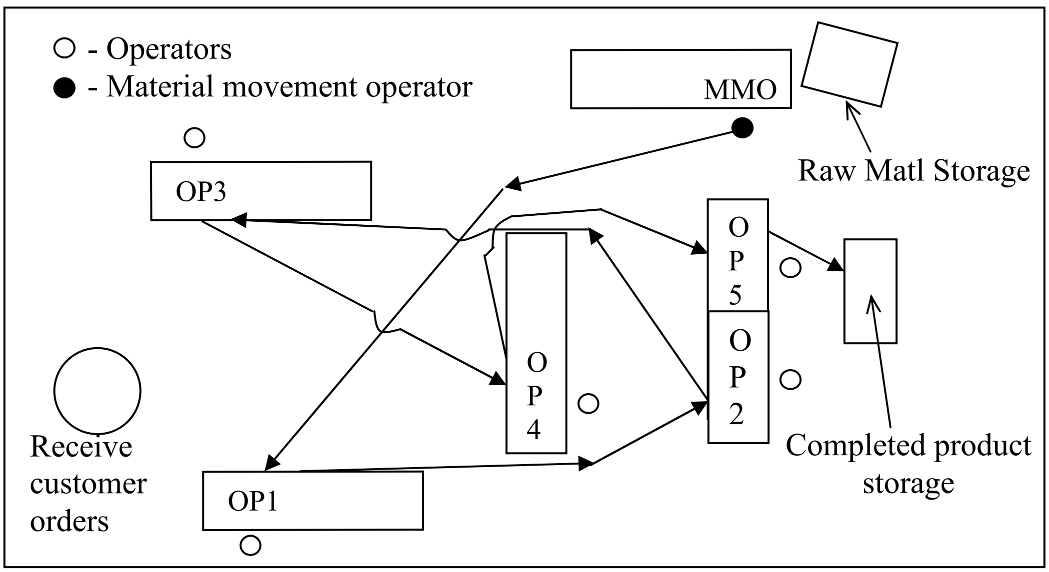



**FIGURE 2.0** INITIAL LAYOUT WITH ASSEMBLY PROCESS PATH.

Over a 30-minute period this production system produced six wagons and only one wagon passed final inspection as a good product.

## VI. Original Simulation Observations

The initial simulation was certainly a collection of extreme cases and very rarely would all this waste be isolated to a single production environment. However, it was very obvious that this production system was not working well and very frustrating for the MMO. The raw materials for all the operations and the completed in-process parts were all in a single container. This method of transportation made things more confusing and more difficult as the order got further through the process.

The layout of the production cell did not consider the production flow from operation to operation. The bottlenecks were at operation #2 (wheel assemblies) and operation #5 (final assembly). Even though the other operators had very light workloads, they made errors because of the routing sheet complexity and the lack of training. Also, the under worked operators were not cross-trained to help out the bottleneck areas. Even if they were cross-trained, the union contract would not allow the operator to assist another operator.

Only so much could be done to improve this push production system. This system could be adjusted to run more efficient than it was originally setup and still be a push system. However, to obtain the best productivity and effective production process for this assembly project, students needed to design a new process.

## VII. Establishing Direction – An Example of Student Implementation, Team I

Team I held a meeting to discuss the initial simulation and to identify areas of the assembly process that could be improved in order to achieve maximum throughput in the production system. The team utilized brainstorming techniques to address their concerns and then addressed the changes that in order to improve the process. Finally, the team developed a plan of action to aid in the implementation of the improved changes.

Initially, the team members discussed the obvious deficiencies of the initial simulation and then identified the following areas needing to be addressed; the production control system, raw materials handling, facility layout, cross training, line balancing, card signaling for raw materials, and quality control. These are the primary areas that the team focused their efforts in order to maximize improvement. These are the same concepts discussed in the classroom. But since the students were able to relate the concepts and philosophies taught in class to the simulation, they implemented solutions quickly. This type of "meaningful learning", which is relating new information to information already known by the student not only reinforces the importance of the content of course material but also enables the student to apply what they have learned with confidence.

The production control system was changed to a pull system with six wagons in process. Six in-process wagons are chosen to ensure success of the implemented changes. Then the plan was to improve and refine the production by decreasing the in-process inventory to expose the obstacles in the production pipeline. If only one in-process wagon was used for the introduction of a major production change, the possibility of too many problems could arise and obscure the initial benefit of the change. For the actual simulation, the in-process wagons were reduced to three. Figure 3.0 shows in process pull signal Kanban mechanism. In Kanban, an order release does not occur until the level of stock at the downstream buffer reaches a pre-specified minimum. In the simulation case, an empty slot signals the upstream operation to produce another subassembly.

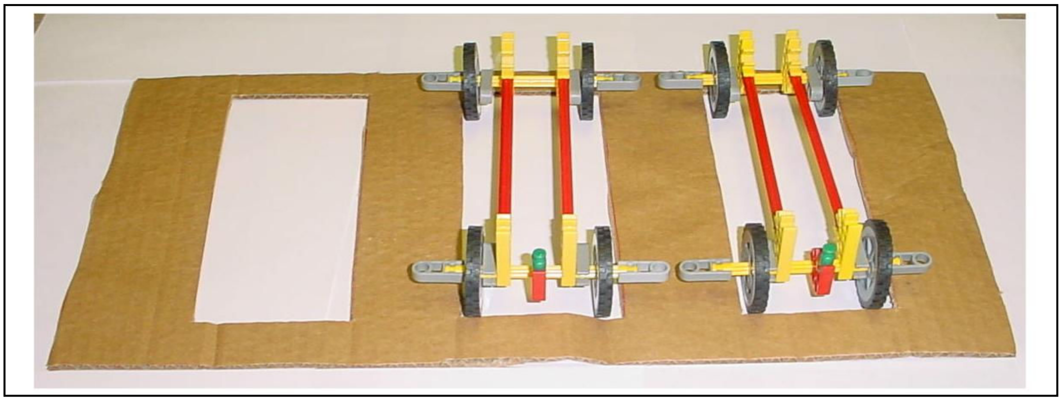


**FIGURE 3.0** INPROCESS ASSEMBLIES IN A KANBAN SIGNALING DEVICE.

Line balancing was examined to determine the best break down of the assembly process. The team tried several different variations and determined that the following order and number of operators to be the best. One operator to assemble tires and wheels; two operators to produce axle assemblies; one person to assemble the frame and then assemble the frame with two axle assemblies; one person to assemble the handle assembly and then assemble the handle to the now in process assembly; and finally one person to assemble the bed and then assemble the bed to the in process assembly. Therefore, six operators total are required for this assembly process. Once the line balancing was completed the next step was to work on the facility layout. See Figure 4.0 for the order of operations and the layout of the work cell (the raw material storage is to replenish the stock at each operation). The actual production layout can be seen in Figure 4.0.

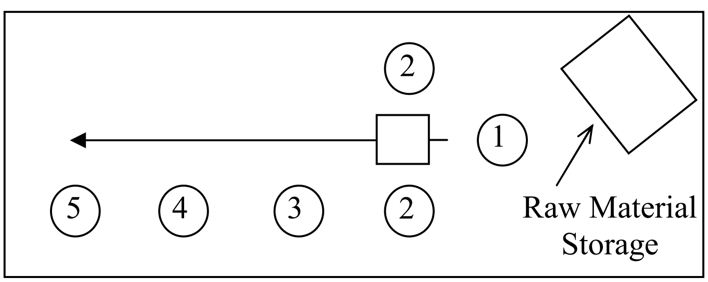
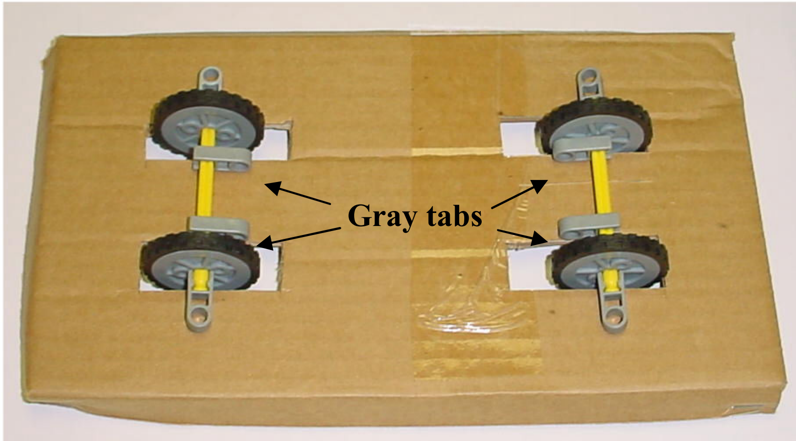
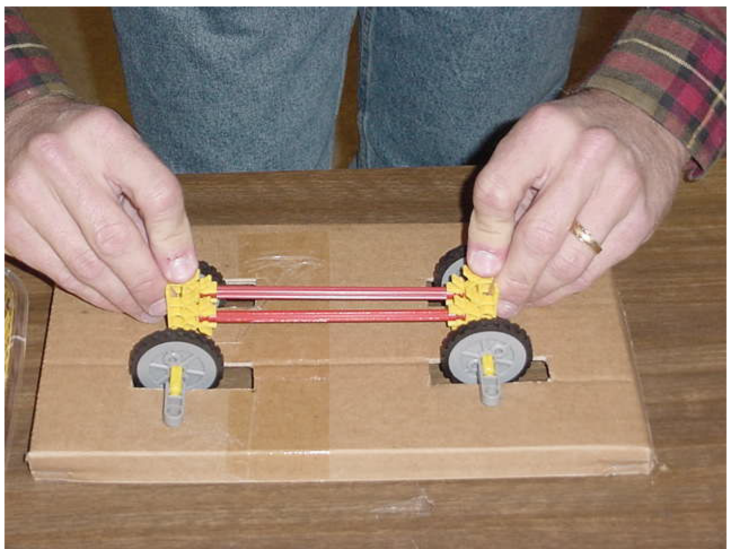



**FIGURE 4.0** ASSEMBLY PRODUCTION LAYOUT.

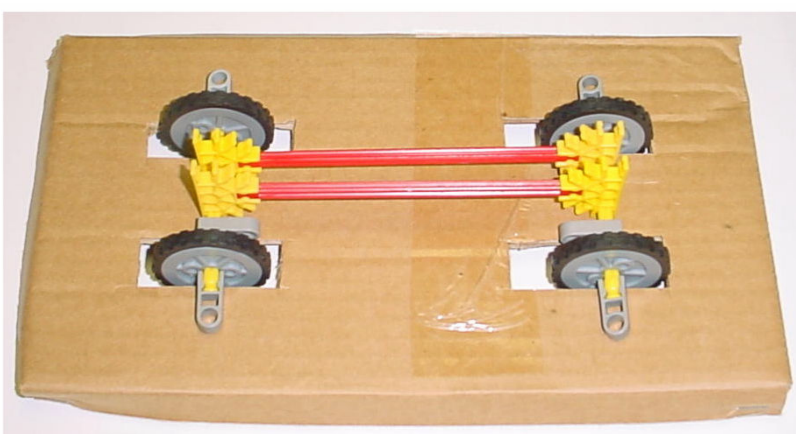
Also, while the team worked on balancing the production line, it became apparent that while assembling two rails to the wheel axle assembly, it was very difficult to keep the gray spacers horizontal as required for the assembly. Therefore, a fixture was designed to keep the gray spacers horizontal and wheel assemblies properly spaced apart for assembling (See Figure 5.0).




Fixture designed to properly position gray tabs horizontally



Fixture in use during the simulation



Completed assembly

**FIGURE 5.0** FIXTURE IN USE TO PROPERLY POSITION WHEEL ASSEMBLIES FOR RAIL ASSEMBLY.

Raw materials stocked and controlled at each operation. Only the raw materials required for each operation are located at the operation. To ensure that each operation would not run out of raw materials, a card signaling system was established. When raw materials got below a certain level, a yellow card is placed on top of the bin. When raw materials ran out a red card is placed on top of the bin (See Figures 6.0). The wheel assembly operation was identified as having the lowest cycle time and was cross-trained to replenish the raw materials for the whole work cell (See #1 in Figure 4.0).

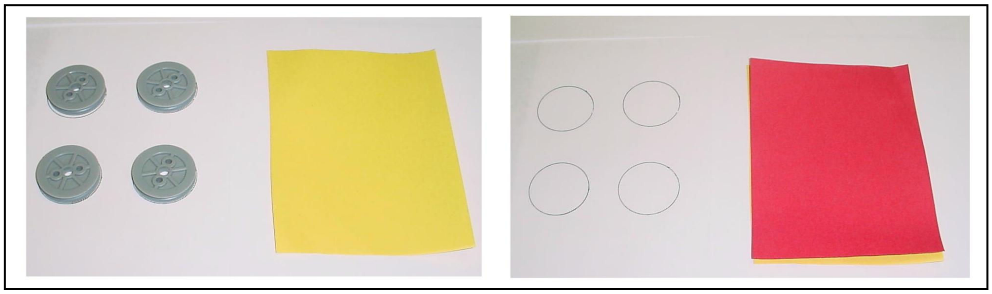


**FIGURE 6.0** RAW MATERIALS CARD SIGNALING SYSTEM.

Cross training was identified as a way to prevent production delays or stoppages. To have employees trained to do multiple things within a work cell required that the union contract be renegotiated. The contract was successfully renegotiated to support the proposed change. This alone doesn't make cross training successful, other mechanisms must be provided.

Studies have shown that after training, if an employee does not regularly use what they have learned they will lose some of their newly acquired skills. To help recover what may have been lost over time, the operator stations were equipped with pictures of the raw material needed for the specific operation, the completed assembled view of the operation. Also included were pictures of the in process assembly views. This system allows an operator who has been trained to perform this operation to be re-familiarized with the process. An example of this is shown in Figure 7.0 for operation #3 of the new production system.

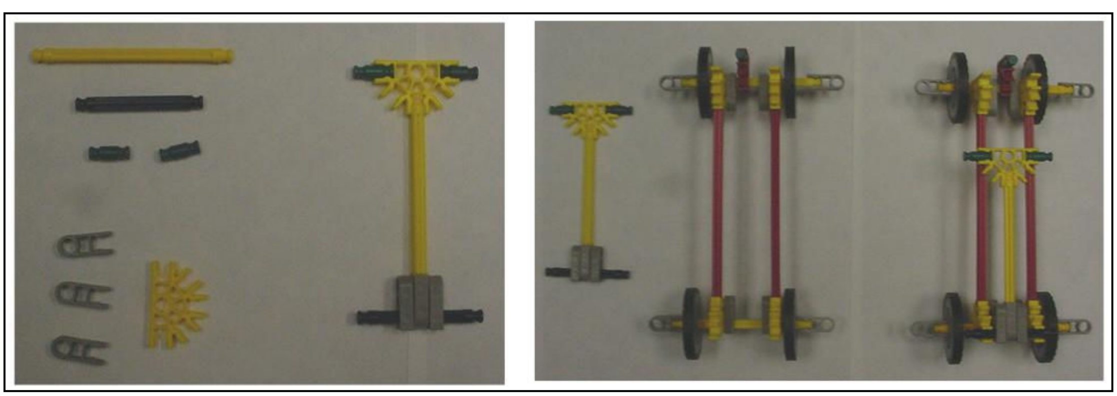


**FIGURE 7.0** OPERATION #3 VISUAL PROCEDURE REFERENCES.

An important item was the issue of quality to make sure that the product was produced with the highest quality and to eliminate any chance of defective parts being passed to the next operation.

This meant implementing quality at the source; every operator is responsible to make sure their operation is performed without any defects. If a defect is identified, then the employee was responsible to immediately correct the problem if possible. If the problem could not be quickly resolved, then the production line was stopped.

## VIII. Implementation of Classroom Concepts, Philosophies and Tools

The following improvements were implemented into a second simulation:

- Pull signal Kanban mechanism
- First run of the proposed balanced line
- Assembly fixtures
- Raw materials segregated for each operation
- Raw material signaling device
- In-process assemblies for three wagons
- Operation assembly pictures at each station (for cross training situations and quality at the source verification)

The improvements listed above, were some of the concepts that were reviewed in the classroom prior to conducting the simulation and came from the course text, Competitive Manufacturing Management.[4] The implementation of these improvements can be seen in Figure 8.0. This is a view of the operation just before the simulation took place.

**FIGURE 8.0** ACTUAL LAYOUT SHOWING OPERATIONS 2 THRU 5.

A pull production system begins at the customer's request for a specific number of completed products. Once these parts are removed from the stock area, it signals the last operation to replenish the removed products. This operation will then remove the required amount of in process stock from next previous operation. This moves up stream in the production process to the first operation. The first operation was the tire assembly process. Since three wagons were in process through each operation, this required operation 1 to have twelve wheel assemblies in process. The Kanban signaling system for the wheel assemblies can be seen in Figure 9.0. Notice that the device signals to the operator that four wheel assemblies need to be produced. The Kanban signaling system was in place for each operation and the finished storage area.

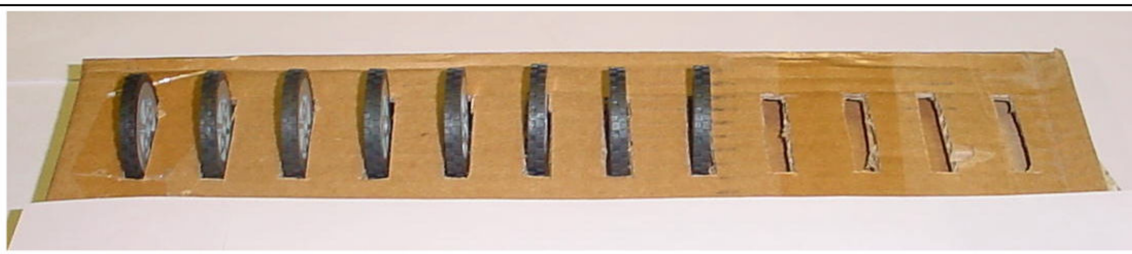


**FIGURE 9.0** FIRST OPERATION KANBAN CONTAINER FOR IN PROCESS WHEEL ASSEMBLIES.

## IX. Alternative Team Implementation and Observations

The second team, Team II, using six operators, began with a pull production system. They put the wheel and wheel axle assembly at the end of their production process. As production began, a bottleneck developed at the wheel and wheel axle assembly operation. In a pull production system, the up stream operations would have been signaled to stop because their in-process inventory would not decrease. Therefore, the system broke down in to a push system because no mechanisms were in place to control over production. Team II did cross train their operators; however they had no mechanism to signal the "floater" to move labor directly where it was needed (bottleneck areas). Team II produced 13 wagons and only eight of them were built to required specification. The results indicate that this production system failed. Figure 10.0 shows this team in production and their production layout.

**FIGURE 10.0** TEAM II IN PRODUCTION.

The final team, Team III, implemented a pull production control system. Their process required seven people to produce wagons. Team III utilized the, "one piece flow" approach. Their system required only one wagon in process and it seemed to work because they had a very well balanced production line. This was obvious during their simulation because none of the operators appeared to be working excessively fast when compared to others in the production line. The team focused on balancing the work on the line and instituted quality at the source. This helped them produce 28 wagons of which 26 were good. Figure 11.0 shows this team in full production.

**FIGURE 11.0** TEAM III IN PRODUCTION.

## X. Conclusions

This activity based exercise was invaluable to the students and instructor because it integrated both the classroom concepts and philosophies that are associated with lean manufacturing and the implementation of those concepts. For the students, working as a team and attempting to implement different solutions to improve the assembly production system was an experience that was not different from what they may face as engineers in industry. In addition, through this process of active learning, student understanding of course material increased. Students who had a good understanding of course content were able to increase their understanding of course material because in some cases, they served as "teacher" for a few members of their team who perhaps could not grasp the concepts. For the instructor, the exercise was a tool that was used to not only reinforce classroom concepts but also a tool that emphasized the importance of not only being responsible for successfully implementing necessary changes in a competitive environment versus just listing what must be done.

## XI. Summary

As stated in their paper, *Active Learning in the College Classroom*, Faust and Paulson state that "active learning is any learning activity engaged in by students in a classroom other than listening passively to an instructor's lecture." The Wagons-R-Us simulation serves as a tool that supplements the classroom lectures regarding the concepts of lean manufacturing. Many of our young engineers upon graduation will face the elements and affects of global competition. Understanding how to implement the tools that will help them remain competitive within their industry is an invaluable experience that cannot be taught in a traditional classroom environment where the instructor serves only as a lecturer.

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**Bibliography**

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