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Carter Cranks: An Interactive Class Room Production Exercise

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Abstract

Most undergraduate students have never seen a production process, thus have no visualization of lecture material presented. We provide an exercise that:

- gives intense, interactive exposure to challenges in a production environment
- gives appreciation of the importance of training, layout, line balancing and cellularization
- provides experience of the potential havoc

Activity simulates multi-workstation manufacturing. Each station has a number of component parts that assemble into the product. The goal is to complete as many jobs as possible during the allotted time. Students are assigned positions (operator, scheduler, material-handler, production control, inspector, or accountant) and perform tasks per work orders and routing slips associated with each job according to the parts list and prototypes provided. Operational problems are expected, and students must face them as they arise.

Afterward, students answer questions about their experience and observations. Instructor conducts a discussion that solidifies the clarity of teaching points.

Introduction

More and more research illustrates that today's institutions of higher learning need to provide a better means of educating and teaching than the traditional read, lecture and test methods. Research supporting this need, as well as positive learning outcomes for students when this need is met, can be found across disciplines in academic areas such as business, psychology, and education. Situated learning theory emphasizing the concept of cognitive apprenticeship and a need for newer methods of teaching beyond involving active perception and participation over rote memorization has been suggested by Brown, Collins & Duguid (1989), and has been found to a better and more appealing way to educate students (Reiser & Dempsey, 2002).

Given the strong research background supporting applied learning styles; as well as the very real need for students to enter the workforce with real world experience, it is our responsibility as educators, to rethink how we teach and prepare our students in order to meet their evolving learning needs. Weast (1996) notes that higher education recognizes the need for alternative teaching methods and a shift away from the outdated methods. With this clear need for broadening our teaching repertoire in mind, we focus on one particular teaching method that research has illustrated helps students better understand material through innovative activity based projects (Gloeckner, Love, & Mallette, 1995), and while the underlying concept of the activity first and foremost educational, it is also a fun learning activity for the students.

Background

Carter Cranks is a fictional company created to demonstrate the challenges of scheduling and managing a Job Shop. The Carter Cranks operation was developed as an in class exercise for students enrolled in an operations management survey course. The exercise takes places during one 50-minute class period. The students are introduced to Carter Cranks through a handout the class period before the actual activity begins (Appendix A). The Carter Cranks exercise is an effective teaching tool when conducted prior to lecturing on scheduling. Students who have an experience are more receptive to ways to improve it.

Our classroom activity simulates a multi-workstation manufacturing facility. Each station has a number of component parts that are assembled into the finished product. The goal of the activity is to complete as many jobs (orders) as possible during the allotted time. The students are assigned to various positions within the organization and perform tasks as identified in the work orders (see Appendix B for example) and routing slips associated with each job. The associated bills-of-material and prototypes are provided to inform students of the required parts and an example of the finished product. As in real-world manufacturing, operational problems are expected, and students must face and resolve them as they arise. Following the exercise, students answer questions about their experience and discuss their observations.

Activity

Carter Cranks is a Job Shop that produces batches of mechanical parts for a variety of customers. Carter Cranks employees are dedicated to the production of high quality parts and on-time delivery. To achieve the goal employees must produce as many quality parts as possible in the time allotted.

Students interested in becoming a Carter Cranks employee sign the sign-up sheet (Appendix C) at the start of class. Employees are paid in class activity (homework) points. Student employees must successfully perform their assigned job in order to earn maximum points. To better prepare students to perform their job, a description of the Carter Cranks operation and job responsibilities is provided ahead of time. While Heizer and Render (2004) identified loading the work centers in one of two forms: “One is oriented to capacity; the second is related to assigning specific jobs to work centers,” the student dispatchers must try to schedule the jobs through their work centers to minimize job lateness and idle time.

The class following the distribution of the handout is devoted to the exercise and discussion. The instructor converts the room from a classroom to the Carter Cranks Company factory. This conversion consists of a series of signs designating workstations, inspection stations and accounting department. The instructor also places the inventory needed to complete the work orders at each workstation. It is essential that the students arrive on time to allow enough time to complete both the exercise and in-class discussion questions in a 50-minute class period.

When the students arrive, they are provided the opportunity to become Carter Cranks employees. The employees are hired from the sign-up sheet. The instructor provides the employees with the documents and materials needed to perform their designated jobs. For example, the Accountant is given an Accounting Report form and the Production Control clerk is given a stopwatch. The instructor answers questions regarding the operating procedure and then begins the Carter Cranks exercise. After finishing the exercise the employees complete forms tracking quality and lateness for each work order.

Operating Procedure

The Carter Cranks operation consists of four workstations, each supplied with various required materials (Table 1). Carter Cranks is staffed as follows: Manager, Production Control Clerk, 2 Material Handlers, 4 Dispatchers (1 per workstation), 4 Assemblers (1 per workstation), Quality Assurance Technician, Accountant, 3 Disassemblers (see Appendix D for brief job descriptions of their duties).

Table 1 – Workstation Material Inventories

Workstation	Materials Needed
Workstation #1	machine screws
Workstation #2	washers
Workstation #3	miscellaneous parts
Workstation #4	nuts

When dealing with smaller class sizes, the exercise can be altered to fit the number of students. Carter Cranks is designed for maximum student involvement. If fewer than 16 students are present in the class, some modifications are possible to adapt to the smaller class size. One material handler can support multiple work centers. The Production Control and

Accounting roles can be combined, and the disassembly can be manned by others doing double duty. For very small classes the dispatcher and operator duties can be combined and performed by one person.

The operation begins with the Manager (instructor) giving the Work Orders to the Material Handler and the Production Control Clerk starting the stopwatch. For each Work Order the Material Handler locates the appropriate prototype (used in lieu of engineering drawings or job instructions). The Material Handler looks at the Routing section of the Work Order to determine which workstation is listed first. The Material Handler brings the prototype, Work Order and an empty bin to the Dispatcher for the designated workstation.

The Dispatcher assigned to each workstation determines the order of the jobs that the Assemblers will work. Using the information on the Work Order and looking at the prototype, the Assemblers add the required components to the assemblies. The Assemblers must focus on doing a quality job, as inspection will identify any nonconforming product. After completing the required task, the Assemblers pass the job back to the Dispatcher. The Dispatcher crosses off the appropriate workstation number and puts the job in the Output area.

One of the Material Handlers picks up the job from the Output area and moves it to the Input area of the next workstation shown in the Routing section of the Work Order. The Material Handler moves any completed jobs to the Quality Assurance Technician. If the parts produced match the prototype and are the correct quantity, the Quality Assurance Technician initials the Work Order and places the job in the Accepted area. If not, the Quality Assurance Technician marks the Work Order “Reject” and places the job in the Rejected area. The Quality Assurance Technician advises the Material Handler of the reason for the rejection. The Material Handler returns the rejected job to the appropriate workstation for rework and correction.

The Quality Assurance Technician moves the Accepted jobs from the Accepted area to the Production Control Clerk. The Production Control Clerk records the arrival time on the Work Order. By comparing the actual time of arrival with the required due date the Production Control Clerk records yes or no in the "On Time" line. The Production Control Clerk gives the Work Order to the Accountant. The Production Control Clerk gives the bin containing the completed job and prototype to the Disassembly Team.

The Accountant records due dates and completion times on the form provided (Appendix E). The Accountant also calculates makespan, average completion time, mean job lateness, percentage late and percentage jobs reworked. These calculations are recorded on the form. The Accountant is responsible for reporting the results to the employees during the discussion session. The Disassembly Team takes the prototype bags and places them in a pile. All produced parts are taken apart and sorted into piles of the same component type. Empty bins are stacked for reuse.

The process continues for the entire designated time, usually 40 minutes, at which time the manager (instructor) signals the end of the shift (activity).

Discussion Questions and Exercise Wrap-up

Immediately following the Carter Cranks exercise, the in-class discussion questions are distributed (Appendix F). The students are given time to discuss the questions in groups. As a way to encourage participation, students can be given credit for correct answers. If the students are having difficulty answering the discussion questions, the instructor provides additional examples and details. As a wrap-up to the activity, the Accountant presents the Accounting Report that identifies Makespan, Average Completion Time and Mean Job Lateness. The instructor leads the students in a discussion of the Accounting Report measures and any remaining in-class discussion questions.

The lecture following the in-class exercise (next class period) is devoted to job shop scheduling and facility layout. This lecture includes priority rules and effectiveness measures (completion time, utilization, job lateness and jobs in system). The lecture also covers various layout strategies (process, product, assembly line). The instructor uses the Carter Cranks Company experience as the basis for this and many future lectures.

Summary

This activity provides a variety of learning opportunities. The in-class exercise can be used to teach Operations Management survey course topics such as, Job Shop Scheduling (priority rules, effectiveness measures), Facility Layout (process, product, assembly line, work cells, line balancing), Product Documentation (BOM, routing, ECN), Quality Management (Cost of Quality), Job Design (job descriptions, job classifications, job enlargement and enhancement).

Another advantage of the Carter Cranks type classroom activity is that it addresses the problem that too many business students' courses in accounting, marketing, human resources and operations tend to appear independent and unrelated. The Carter Cranks exercise provides the student the opportunity to learn the importance of cross-functional interaction. Carter Cranks is a structured yet very flexible in-class exercise. The instructor can use Carter Cranks as a platform for teaching a variety of Operations Management topics.

Ormrod (2004) suggests that cooperative learning activities such as Carter Cranks, presented in the form of group problem solving, is an effective means of developing problem solving strategies in learners. In a study of alternative teaching strategies, Weast (1996) found that those students learning in the traditional method of absorption of information were not able to intellectually determine when to accept or reject controversial concepts, while those learning with a critical thinking element were better equipped to challenge the reasons and evidence based on their validity and soundness. This activity based in-class project requires students to think critically through their actions and decisions to complete the assignment, giving them a practical experience in the real world of operations management, which will better equip them in future decision making situations.

References

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Appendix A – Class Handout

MGT 325 – Job Shop Scheduling For Carter Cranks

It is very important to be here on time for this class

Carter Cranks is located in Booneville, Indiana. In the early 1900's it produced cranks for the Model T and other early automobiles. Over the 90 years since they have evolved into a job shop that produces batches of mechanical parts for many industries. The purpose of this exercise is to demonstrate the production challenges of a job shop environment.

The manufacturing operation consists of four workstations (WS's 1, 2, 3, 4). WS#1 has a supply of four types/sizes of machine screws to use in manufacturing. WS#2 has an adequate supply of four types of washers. WS#3 has eight miscellaneous items ranging from wooden pieces, metal elbows and screw eyes. WS#4 is where the nuts are applied to the work piece -- there are three types of ¼" nuts. Your goal is to produce as many jobs as possible in 40 minutes. Each job will require the manufacture of only a few parts. Imagine the numbers multiplied by 1000's to make this exercise seem more real. Jobs must be circulated through several workstations in the correct order. Often a job will need to visit the same WS more than once.

The material handler picks up the WO's (work orders) from management (the instructor) and the **production control clerk** starts a stopwatch. The **material handler** then locates the prototype for this item and an empty bin and takes the job to the **dispatcher** for the first WS. The WO shows the parts list and the routing. The **dispatcher** assigned to each WS determines what job the operator will work on next (scheduling). He/she should use his or her own judgment based on the due date and observations of what is happening. The dispatcher does no manual labor. Each WS has an **operator** who adds the required component (screw, washer, etc). The operator should not hurry. The objective is to do a quality job.

After the **operator** is has completed the necessary tasks for the job at this stage of manufacture he/she passes it back to the **dispatcher** who crosses off the appropriate W/S number on the routing sequence and puts the job in an output area. A **material handler** picks the job up and moves it to the next WS shown in the routing order.

After completing the routing through the appropriate WS's in the prescribed order, the **material handler** carries the job to **Q/A** (quality assurance). If the products were produced like the prototype and in the correct quantity, the WO is initialed by the **Q/A** technician and put in an out area. If the job was not performed correctly, **Q/A** marks to WO with "REJECT" and puts the job in a reject pile. The **material handler** then consults with the Q/A technician to determine where the job needs to go for rework.

If **Q/A** signs off, then he/she passes the job to the **production control clerk**. The **production control clerk** marks the time of arrival on the WO and compares this time with the due date and records yes or no in the "On Time" line. **The production control clerk** passes the WO to **Accounting** and the bin with the completed job to the **disassembly** crew.

Accounting records the due dates, completion times and calculates Makespan, average completion time, mean job lateness, % late, and % with jobs reworked (see form) and reports results to class.

Disassembly is an important step because management must repeat this exercise at another class. The **disassembly** team does not open the prototype bags. Place them in a pile and stack up the bins. All produced parts should be taken apart and sorted into piles of the same component type.

Appendix B – Work Order Example

Part # 62

Bill of Materials

Work Station 1 -->				Work Station 2 -->				Work Station 3 --->								Work Station 4 -->			
2 1/2" Hex Cap Screw	3" Hex Cap Screw	2" Machine Scew	3" Machine Screw	1/4" Washer	finder washer	split lock washer	tooth lock washer	screw eye	W-1	W-2	W-3	W-4	W-5	L1	L2	1/4" nut	1/4" wing nut	1/4" lock nut	
		2				1									1	2	2		

Work Order No. 13

Quantity 3

Customer Jones Cat Feeding Machines

Due Date: 15 Mins.

W/S Routing 3, 1, 2, 4 (dispatcher cross off as job leaves WS)

Q/A Initials: ML OK? ✓

If no, send to appropriate WS for recycle

Production Control: Initials: WF

Actual Completion Time: 25:25 (see stop watch)

On time?: circle Yes or No

If no, minutes late: 10:25

Appendix C – Class Position Sign-up Sheet

	Job Position	Name
1	Assembler - WS#1	
2	Assembler - WS#2	
3	Assembler - WS#3	
4	Assembler - WS#4	
5	Dispatcher - WS#1	
6	Dispatcher - WS#2	
7	Dispatcher - WS#3	
8	Dispatcher - WS#4	
9	Material Handler - 1st	
10	Material Handler - 2nd	
11	Q/A Technician	
12	Prod. Control	
13	Accounting	
14	Disassembly	
15	Disassembly	
16	Disassembly	

Appendix D – Job Descriptions

Manager (Instructor)

- •Assigns Work (the Work Order, BOM and Routing)
- •Hires the "employees" (students)
- •Answers "employee" questions
- •Pays "employees" bonus points

Production Control Clerk

- •Tracks time (stop watch provided)
- •Delivers QA approved Work Orders to the Accounting Clerk
- •Delivers QA approved completed parts to the Disassemblers

Material Handler

- •Obtains Work Orders from the Manager
- •Locates prototype for each Work Order
- •Delivers prototype, Work Order and empty bin to the Dispatcher
- •Moves work to the appropriate Work Station
- •Moves completed Work Orders to Quality Assurance Technician.
- •Returns Quality Assurance rejects to the appropriate Work Station

Dispatchers (1 per Workstation)

- •Determines workstation schedule (which Work Order should be done next)
- •Assigns Work Orders to the Assembler
- •Obtains completed work from the Assembler and places the work in the Output area. Crosses off the appropriate Work Station number on the Work Order

Assemblers (1 per Workstation)

- •Obtains work from the Dispatcher
- •Performs assigned work according to Work Order and Prototype
- •Passes completed work to the Dispatcher

Quality Assurance Technician

- •Compares completed parts to the prototype and Work Order. If quality and quantity is correct initials Work Order and places in Out Area. If quality and quantity is incorrect marks Work Order "Reject" and places in Reject Area.
- •Passes accepted parts to the Production Control Clerk
- •Passes rejected parts to the Material Handler

Accountant

- •Records due date and completion time (form provided)
- •Calculates makespan, average completion time, mean job lateness, % late and % jobs reworked on the form provided
- •Reports results to the class

Disassemblers

- •Places unopened (DO NOT OPEN) prototypes in a pile
- •Disassembles (takes apart) all produced parts
- •Sorts components
- •Stacks empty bins

Appendix E – Accounting Form

Carter Cranks Accounting Worksheet Section ___________

WO#	Due Date (minutes)	Completion Time (minutes)	**On Quality the first time?**	**On Time?**	**Lateness (minutes)**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
Total	xxxxx				

Makespan (completion time of last job) = ____________
Average Completion Time (sum of the completion times/number of jobs completed) =___________
Mean Job Lateness (total job late minutes/number of jobs completed) = ____________
Percentage of jobs late (100*# late/# completed) = ______________
Percentage of jobs that had quality problems = ______________

Appendix F – Discussion Questions

NAME: _______________ Section:_______

Review questions for discussion (for in-class exercise credit)

Describe any Q/A problems encountered by class

How did the class do at meeting production due dates?

Was there a bottleneck anywhere? If so, what could we do to reduce/eliminate the bottleneck?

What was the approximate % idle time at each WS?
#1 ____
#2 ____
#3 ____
#4 ____

How did the dispatchers choose which jobs to do next (priority rule)?
#1 ______________
#2 ______________
#3 ______________
#4 ______________

If we ran again, what priority rule would be advised?

What type of layout did Carter Cranks choose (process focused, assembly line, product focused, warehouse, office, etc)?

How would you have laid out the work if

a) all jobs followed the same sequence (routings the same) and required the same amount of time at each WS?

b) all jobs followed the same sequence and required different times at each WS?