Industrial Engineering LIVE! Classroom Lab Activities used in an Introductory IE Course and in Recruiting Freshmen

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Abstract

Introduction to Industrial Engineering Courses provide an overview of IE history and common methods that are used by Industrial Engineers to analyze systems and design efficient processes. A series of active labs are integrated into a traditional course where the students are introduced to concepts, apply solution techniques for those concepts with class and homework problems, and then perform labs. These labs were developed to make the topics come alive for Sophomore Industrial Engineers who are still trying to understand their chosen field and have not had their first co-op or IE job. The labs can be done in the classroom with a minimal amount of purchased equipment; some activities only require a trip to the grocery store. These lab activities were also adapted for use in Open Houses and Freshmen Forums to interactively illustrate to first-year engineering students what IE might look like. These and other recruitment activities have more than doubled the enrollment of the IE program at Northeastern University in the last 5 years.

Introduction

In a course entitled *Introduction to Industrial Engineering* at Northeastern University, a broad range of topics is covered quickly, and students can rapidly learn by seeing and doing. Typically, Industrial Engineers don't have chemicals, machining labs, wind tunnels or circuit boards to use in specialized laboratories. The goal in this course was to find a way to include hands-on activities without a formal lab component or facility. These labs are designed to integrate the concepts with models that are memorable. Some of the topics covered by the labs are Process Improvement, Work Measurement, Facility Layout, Assembly Line Balancing (Manufacturing and Production Control), Bin Packing (Material Handling), Human Factors, Operations Research, Engineering Economy, Queueing, and Quality Control. The students generally work in groups, do the lab work, gather data, share class data, and write individual or group lab reports. Some of the labs are computer labs, where they use software tools (mostly Excel) to solve several types of problems. Verbal and written feedback from the students shows that they enjoyed the lab activities, but more importantly, that they felt like many of the concepts finally made sense or "sunk in" after they had seen it in action, even if the labs are only models that represent real working situations.

Only 3% of the first-year engineering students declare themselves as Industrial Engineering majors as they enter the University, yet 9% of the same class are Industrial Engineers as sophomores. If asked, most first-year students have little information about what Industrial Engineering involves or what an IE's role in the engineering world is. In their first-year course entitled Introduction to the Study of Engineering, all students are required to learn about the various engineering majors, and must attend at least two Freshmen Forums run by the Engineering Departments. They are also required to attend a Freshmen Open House, where each professional society tries to interest the freshmen in joining their student chapter. Several of the lab activities were adapted and used at these events. These activities have the students competing to improve methods and processes and have created quite a stir at these events.

This paper describes a selection of the actual labs. These descriptions include the lab requirements for the students, the materials needed, instructions for set up and administration of the lab in classroom settings and insights from experience with using these activities for over 5 years. There are also suggestions on how to adapt some of the activities for use in recruiting venues, or other Industrial Engineering courses. The labs are easy to learn and use, require limited purchasing, have been tested, but are also frequently added to, revised and improved upon.

Motivation and Inspiration

In teaching any course, much of what is developed and tried with students comes from our own classroom experiences, from talking to other faculty about teaching, and from receiving feedback from students, both verbal and non-verbal. In addition, attendance at teaching workshops and conferences that focus on teaching inspires growth. Recently in my teaching career, many colleagues started to use the term *active learning*. The workshop run by NETI solidified some ideas – *In-Class Teams, Problem Based Learning Exercises*, *Group Work* – and added some new methods to some already in use. Work on active learning [3], [5] describes how students learn. Half of the four-part learning cycle is “feeling” (Concrete experience) and “doing” (Active Experimentation). This led to keeping the focus on hands-on experiences in the classroom [9]. A focus on Student-Centered Instruction [2] even helped with the classes where some lecture was done, so that problem-solving and group work was always mixed in. Even more support was provided through attending an ExCEEd workshop (Excellence in Civil Engineering Education), where there were numerous examples of class demonstrations and innovative class activities. The text provided with that workshop continues to be invaluable for teaching, along with Wankat and Oreovicz [11] who state that “Laboratory classes can be structured to reinforce lectures not with cookbook exercises but with the scientific learning cycle.” They provide examples and options for both in-class laboratories and separate laboratory sections. Any of these give the students more impact to their learning.

However, even with this revered group of teaching professionals as background, much of the motivation and inspiration continues to come from the students who call, write or stop by and explain that the labs really helped, they are on the job now and discovering that what was started in lab has really helped them, though they have a lot more to learn. And course evaluations and feedback during the semester still emphasize that they enjoyed the lab work, and learned a lot from it.

The Course: Introduction to Industrial Engineering

The Industrial Engineering (IE) Curriculum at Northeastern University has changed a number of times of the last 10 years. One major change occurred in 2003 when the University transitioned from a quarter system to a semester system. The semester is 14 weeks long, versus the 10 week quarter. Therefore, the course needed to be designed appropriately. Before semesters, the course most resembling Introduction to IE was entitled *Work Design*. Work Design was taught in the *Middler* year (NU is a five year school, and the Middler year is between the Sophomore and Junior years). Although the courses are similar, the emphasis in Work Design was on the traditional basics of IE involving Work Measurement, Methods Improvement and Workplace Design [6]. As the course was taught, some labs were developed concerning time study, and using software to learn about Predetermined Time Systems. Early on, labs were added on Occurrence Sampling, Workplace Design and Ergonomics. As the change to semesters approached, the IE faculty proposed that the course be broadened to truly introduce sophomore IE's to the many areas in the broad discipline of Industrial Engineering. At about the same time, the IE faculty proposed the creation of a minor in Industrial Engineering. One part of that minor was an overview course, which is the Introduction to IE course. This minor has now been approved, and many students are now enrolled through the Mechanical and Industrial Engineering department. Currently, the topics covered in the course are:

- History of Engineering and Industrial Engineering: Development and Scope
- Manufacturing Engineering and Operations Planning
- Facilities Location and Layout
- Material Handling, Distribution and Routing
- Work Design and Work Measurement
- Quality Control
- CAD/CAM. Robotics and Automation
- Human Factors
- Financial Management and Engineering Economy
- Operations Research
- Simulation and Queuing Systems
- Project Management
- Lean Manufacturing, Six Sigma, Supply Chain Management, other current topics…

These topics can change, but follow the current textbook well [10], and seem to be an adequate representation of the field. The format of the course is that it is taught three days a week, in 65 minute sessions. On day one, a topic is introduced, with concepts and techniques shown, preceded by a discussion of problem types and where this type of problem may occur. On day two, further development of the topic ensues, generally with some problem solving done during class, in groups or individually. On the third day of the class there is generally a lab or hands-on activity. These activities are described in more detail in this paper. These labs are designed to illustrate the material, they are simulations of real world problems designed to be achievable in a single class period. The lab reports are focused on having the students apply what they have learned to an application, requiring them to think beyond the "cups and straws" to manufacturing or other examples in the real world.

The materials used in these labs are not costly. Some basic necessities are stopwatches, Legos™, one or two decks of cards, cups and straws for Bucket Brigade, and if possible, nuts and bolts for various assembly tasks. Some other equipment has been acquired such as pegboards with colored pegs, a wooden structure with numbered slots and cards for those slots (numbered 1 through 15) and some electric wands that can be inserted into metal plates with holes of different sizes. Details of how some of these materials are used can be found in the lab descriptions below. Some materials have to be purchased at a grocery store, such as the materials for the Material Handling Lab. This can be a bit more costly, but those materials are used both for that lab and the Freshmen Open House, so that the department has no objection to the cost. In general, the labs have been designed to utilize readily available materials, so that the students understand the technique, and the faculty member does not need to look for serious funds or specialty stores to use these simple labs that simulate real problems.

Descriptions of Introduction to IE Labs

Most of the labs currently used are listed below, with a description of that lab and how it is run in class. Several of the labs are included in the appendix. Any lab is available by contacting the author.

1. Process and Method Improvement

   Purpose: To introduce process and method improvement, and have the students thinking about "Working Smarter, not Harder" by participating in teams on a process to manufacture "cookie treats."

   It is the first class of the semester, and the students are divided into groups of 4 or 5. Each team is given about 40 small cookies, frosting, sprinkles, squirt frosting, plastic wrap and ribbon. They are given some foil to lay on the tables and small knives. They are instructed to make as many "cookie treats" or cookies with everything on top, as they can in 90 seconds. Additionally, they are instructed that each cookie must be individually wrapped to qualify as "complete". Only completed "cookie treats" count. They are given a few minutes to discuss their method and set up, and then they are timed. Before the next 90 second trial, the groups discuss how their assembly process worked, and what changes they will make in the method and process to improve the throughput. A second trial is done, with completed cookies counted. A handout is given out with questions for the teams about what they have learned, how they would apply this to a manufacturing facility, what equipment would help and any suggestions.

   The class can then have a discussion on what Industrial Engineering is, and what they have learned from this experiment. This has been a great introductory exercise; the students get excited about IE, meet each other, and really work hard to find method improvements. It does require a little clean up, and purchasing of the materials. This activity is also used at an Industrial Engineering Forum, to interest first-year students in the field. There is more on that subject at the end of the paper.

2. Assembly Line Balancing and Bucket Brigade

   Purpose: To understand and demonstrate the advantages and disadvantages of two different systems for filling orders; *Bucket Brigade* and *Zone Picking*.

   This is a simple experiment to illustrate two different approaches to process control. Students analyze the results quantitatively to determine the best system and understand how to apply this system**.** This lab is modeled after the work done at Georgia Tech by John Bartholdi [1]. Students are to do order picking, first using a Zone Picking strategy, then using a Bucket Brigade strategy. They compare numerical results for the average time to complete an order, number of orders completed and the number of orders left in process for the two systems, along with observations of the process while it is ongoing. The materials are plastic cups, straws, chopsticks, needle-nose pliers and a stack of "orders". The cups are numbered from 1 to 15 and the students must pick items in order using the tools or their hands.

   In Zone picking, a student has one zone (set of numbered cups) and must only pick the parts (straws) from their zone with their tool. To run the two systems requires three students to do order picking, a timer with stopwatch for each order, a data collector to record times, and usually a material handler/supervisor to keep the system organized and running. The time to complete each order is recorded.

   In Bucket Brigade, students pick up an order from the previous worker when they have completed theirs, like a pull system. The workers are ordered from the slowest to fastest, determined by which tool they are using. Once a few orders are in the system, when the last worker completes an order, they go to the previous worker, take the order they are working on and pick the remaining items. The previous worker then goes to the worker that precedes them and works on that order until the worker after them takes over. After a few moments of confusion, the workers settle into an understanding of the system and work together well, but it requires a bit more communication each time an order is transferred as to where the previous worker left off.

   The students observe more bottlenecks and idle workers in the Zone picking system than in Bucket Brigade, but must also discuss the numerical results, where each type of system might be best suited, and why. The data is collected on a computer in class, and emailed to all of the students. The lab report requires them to find applications of this technique in industries. There are a number of companies, such as Subway, which use Bucket Brigade. Results are consistent every time this lab has been run and the concepts transfer well to other systems and applications.

3. Facility Layout – Playground Design

   Purpose: To practice Facility layout and design on a realistic problem in groups, addressing the solution presentation to a client.

A Playground Design Game is adapted from [8]. The students are given objectives, activities representing what children do outdoors, suggestions for playground zones and a large number of playground equipment options. As a group, the playground designers must choose a limited number of these objectives (4 or less), create zones and activities, and then select equipment based on these guidelines. They must come to a consensus on what should be in their playground, and then design it. They must be aware of the customer needs, and sell the customer on their design. They are required to formulate an attractive drawing, poster or visual representation of their playground.

This lab was added this year, and turned out to be a good addition. It gave the class a chance to think like consultants, and consider customer needs. It was different than using the traditional SLP (Systematic Layout Planning) that they had learned in class, and done for homework, so it gave them a different perspective on layout work. Some very creative designs were generated, they learned from a different perspective, and had fun.

4. Bin Packing Algorithms

Purpose: To use material handling principles, and to apply a method or an algorithm to optimize the application of material handling in the activity of packing groceries efficiently.

Students are given two boxes and a large number of grocery items, usually at least two of each item, and instructed to pack the boxes efficiently, filling them only to the top, and without harming any items. In addition, the boxes must be close to the same weight and the weight in each box must be evenly distributed. A detailed lab write-up is included as an appendix to this paper. Students are allowed three minutes to work with the items and boxes and decide on an approach or algorithm for their packing, which they must write down for reference when they pack and for their report. After each team of 4 or less has had a chance to strategize, one student is selected to pack the boxes.

One note, the instructor should place the items around the boxes, not allowing the students to stage the items in any particular way. Students have been known to stack the items in a pre-ordered way, then place the box on top and turn the whole thing over, which defeated the purpose of having them design some sort of algorithm. Each team has two rounds of packing, where they watch all teams once, and can improve their method for the second round. The instructor records the time to pack, the number of items left out, and quality of the packing (items crushed, uneven weight).

In class, we discuss how each team accomplished the task, and differences in approaches. Because only one student packs the boxes, sometimes we get tangled up in individual capabilities. But the emphasis in the lab writeup is for the students to review the Material Handling Principles, and discuss which apply in this example. They must review their own algorithm's effectiveness, and find material on Bin Packing algorithms to compare with theirs. As a result of this lab, the students should have a better understanding of Material Handling issues, and how algorithmic approaches can be applied to problems.

5. Time Study

Purpose: To apply stopwatch time study, conduct performance rating of workers and computation of time standards. Evaluate where and how to use time study information.

Stations are set up (usually 6) with tasks that must be accomplished at these stations. These tasks must take about the same amount of time, less than 2 minutes apiece. Some tasks might be sorting items, such as Legos™ into bins, or pasta into plastic bags, assembling nuts and bolts, dealing cards, collating and clipping papers together. Good candidate tasks are those that can be accomplished by one person in a short time. To understand performance rating, the student doing the task is to carry out the task at some rate besides 100%, but not tell the timers. The timers are to guess what rate the student is working at; time the student and then the task is performed again at a different rate. This provides discussion points and variation in the data, along with values used to compute time standards. Students are formed into groups that rotate among the stations. The write-up for this lab is in the appendix.

Most students finish this lab hoping they will not have to do a lot of time study, and recognizing that rating performance is difficult. This reinforces the concept of using predetermined time systems, but also allows for discussion of why time study is needed, and how best to obtain this type of data. Understanding and working with data is also a skill that is further developed as they write this report.

6. Statistical Process Control

Purpose: Apply statistical analysis techniques to data sets using Excel. Review the results for decisions on statistical process control.

This lab is done in a computer classroom using Excel to apply a number of different statistical process control techniques. Other techniques are covered in class and through homework problems. The lab has the students construct a histogram using a given data set and interpret the results. They must then use another data set to construct a graph, fit a trend line and interpret the results. The last exercise has the students create process control charts, analyze the results and make decisions as to whether a process is in control or out of control. There is special software for Statistical Process Control, but the students can accomplish the analysis with the tool that they all have access to. Data was obtained from problems in textbooks like [7].

This lab can be done without a computer classroom, but would be more difficult. Although most students are familiar with Excel, many have not constructed a histogram, and also need practice on graphing and fitting trend lines. This lab can also be done in pairs, especially if fewer computers are available.

7. Human Factors

   Purpose: Apply Human Factors Principles to work and interpret the Human Interface with work. Illustrate auditory vs. visual interface applications.

   Students are paired up. Some of the pairs are given neckties; some are given Lego™ cars that are preconstructed with identical parts. The student pairs with ties are instructed to write instructions on how to tie a tie, no pictures allowed. Simultaneously, half of the pairs that have Lego™ cars are instructed to write instructions on how to build the car without any pictures, only words. The other half that have cars are to write instructions that are mainly pictures with few words. Once all groups are done, the group with ties gives the neckties to a selected group, usually the women in the class, or the least experienced in tying a tie. Then volunteers are found to give verbal one-on-one instruction on tying a tie to this inexperienced group. The rest of the class observes as the group with ties tries to follow verbal instructions. Then another group tries to tie the ties by following the written instructions, of course, with mixed levels of success. The class discusses what is the easiest way to learn how to master a skill and realizes that this may be done best by modeling and verbal instructions (their fathers showed them how to tie a tie by standing behind them or with them in the mirror). Yet, for many devices or techniques, only written instruction is provided.

   While some groups are trying to follow instructions for tying a tie, other groups are given instructions to build Lego cars. They try to reconstruct the cars exactly as given in their instruction set. It was expected that instructions with pictures would be superior to those using only words and this was found to be true for the most part, although some students appeared to be able to write superior steps for building with such quality and care that they were almost as good as pictures. Both exercises helped the students understand some principles of the human interface in performing work.

8. Operations Research – Linear Programming and Assignment Problem

   Purpose: To solve linear programming problems using a graphical technique and using the Solver on Excel. To solve an assignment problem using the Hungarian Method. To apply Operations Research techniques to problems and understand the formulation and meaning of the solution.

   This lab is held in a computer classroom. Using a simple Linear programming problem with two unknowns, the students first solve it graphically [4]. Then they are taught how to use Solver on Excel to solve a simple problem. A few what-if scenarios are suggested for the students to try while they are in the lab, and hand in to be sure that they are correct, and that they understand the formulation and results. For homework, they solve other LP problems, along with an assignment problem which they do by hand.

9. Queueing theory and Queueing Systems

   Purpose: To observe, measure and study simulated queueing systems. To write a report, comparing mathematical model results of queuing systems to collected lab data.

   In order to simulate single server queueing systems with different distributions for service times, three servers (people) were assigned, each with a deck of cards. One server was to deal cards for exactly one minute whenever a customer arrived. The second server was to deal cards into two categories, taking about one minute, but be sure to work at different speeds so as to create some variation in that service time, approximating exponential service time distribution. The last server was to sort the cards in different ways every time, each taking around one minute, but try to add more variation, to simulate arbitrary service time distribution with a larger variance. Customer arrivals were simulated by having students serve as customer generators for each service, where they generate a customer approximately every 72 seconds (50 per hour). Then students are assigned at each station to record the waiting times of each customer, the service times, and the number in the queue. The simulation is maintained for most of the period. The data is sent to all of the class, and the students are required to analyze the data, and compare it to the results from formulas for each type of system. In their reports, the students compare the theoretical results to the simulation, and explain why differences may occur. They also discuss their understanding of queueing, and which system may be preferred. The write-up for this lab is included in the Appendix.

   This lab is challenging to administer, given all of the variation and so many people with so many jobs occurring simultaneously. The participants need to understand their jobs and the impact of their timing on the system. The constant service time system runs as expected, but the other two systems designed to simulate exponential and arbitrary service times, often do not behave as structured. The students that are carefully observant usually can discern that real world systems rarely run as predicted and can explain what caused the simulation to be different from their formulas. It opens up excellent discussions when reviewing the lab and discussing what was learned.

The descriptions above may be adequate to utilize the labs in a similar class, but if more details are desired, the Appendix contains more complete Lab Assignment sheets for selected labs. If further information is desired, contact the author with questions (sfreeman@coe.neu.edu). I am happy to have other educators who desire to, use any of these exercises.

Adaptation for Freshmen Open House and Industrial Engineering Forum

Shortly after the Fall semester is in session, the College of Engineering holds an event called the Freshmen Open House. All engineering freshmen are required to attend. The Student Chapters of the professional societies such as ASCE, ASME and IIE are given an opportunity to demonstrate to the first-year students the many good reasons to become involved. To liven up the demonstrations, the officers of IIE have utilized several of these lab activities to encourage students to participate and learn more about Industrial Engineering. We posted a sign behind the tables that said “It’s all about the method”, and then had students compete to beat each other in speed at placing pegs in pegboards, sorting Legos into bins, and packing grocery boxes. We had many prizes and posted winning times. Students got excited to compete, being sure that they could do it better, and that their method was superior. With the box packing, we had two side-by-side setups so that they competed directly against someone else. At another table, there were computer applications set up showing Simulation using *Arena* to simulate Bottle Manufacturing. Another simulation depicted the operation of an Emergency Room. The IIE team has really enjoyed the Open House more, and it appears that the first-year students are at least more curious, if not seriously interested in Industrial Engineering after adding these activities.

During the Fall semester, first-year students must attend Freshmen Forums. These are held every week by each of the major engineering departments in order to give freshmen information about each major so that they can make an informed choice. The Industrial Engineering forum has been orchestrated to pique the student's interest. There are student speakers, faculty speakers, and many IE students there participating enthusiastically. A number of upper-class students talk about their co-op jobs, a selection of students talk about why they decided to become IE's and the faculty talk about their experience in Industrial Engineering. In the midst is the first lab, which was the method improvement of Cookie Treat production. This is demonstrated by some students from class, where they intentionally do a poor job. After a few more speakers, volunteers must try to improve the process. Several freshmen students come up front to beat the IE's. It generates excitement (add some fun music), and gets much of the audience involved. The forum is completed by some of the IE students listing the top ten reasons to become an IE. Throughout the forum, it is evident that there are many IE students who are friends, participating, chatting, and enjoying being part of the department.

Conclusion

Teaching a course with a broad range of topics to students new to the field of Industrial Engineering means that there is only a short time for the students to get a feel for that topic. Therefore, a hands-on exercise, a model, a simulation, a lab; any or all of these allow the students to participate in the new topic which subsequently helps the subject sink in and gives them a taste of upcoming work. NU is a cooperative education institution; practice-oriented education is a byword for educators on campus. Most of these students will not "practice" until the start their first co-op jobs that year. Anything that helps them prepare, increases their ability to recognize a problem type, and gets them excited about Industrial Engineering is worth trying. Although the course still requires material to be discussed in traditional ways, the addition of in-class lab exercises and activities has livened up the class, and helped the students learn the material along with obtaining a little practice and experience in their new field.

Introducing freshmen to Industrial Engineering is an additional challenge. When they can see a production line, improve a method, work smarter not harder, be more efficient and have fun, they have an opportunity to experience IE in a new light, and understand some of the basic precepts. Forums already in place provided the means for exposing freshmen to IE, it just required a substitution of active demonstrations, infused by enthusiastic upper-class students. The program has grown, the introduction course (formerly called Work Design) had 10 students only 5 years ago. This fall there were 24, the IIE Student Chapter is thriving and it is great to have so many students excited about being Industrial Engineers.

Appendix: Detailed Lab Assignments on Selected Labs

Lab Project #3

Objective of the lab: Using material handling principles, apply a method or an algorithm to optimize the packing task.

Description:

You have two boxes to pack with the items shown. You have weight and space considerations, plus the speed at which you can pack the boxes.

For weight, the boxes must be approximately the same weight, you will be judged by lifting them. You must try to pack the boxes as evenly as possible and fit in as many items as you can.

First review the items and their relative weights and sizes and work with your group to decide on a strategy to pack the boxes before actually trying to pack them. Then you will be given a few minutes to try your strategy on the actual boxes before getting back together with your group. You will make any desired changes to improve your result before showing the rest of the group and being timed.

Task:

Select one person from your group to pack the box. This person will follow your method after testing and revising. Then your group will be observed and timed for how fast the representative packed the box, and how many items were packed correctly. Record your heuristic and result carefully.

Report

Write a brief report outlining your results. First write an objective statement for the lab. Then have a section describing your algorithm or heuristic for box packing. Look at the 19 Material Handling Principles from the text. Discuss if any apply, and what ones you would use if you were scaling this up to say packing groceries for a grocery delivery service such as Peapod. Your next section should describe the activities and process followed by your group with your result. Another section discusses what you learned from the other groups. A final section includes a discussion of an article or reference material on packing, or shipping such as bin packing. You must reference this information properly and attach the article or material found as an appendix. Your last section describes what you learned from this process.

Things for the boxes: Paper towel, Toilet paper, Cereal, Instant lunches, Water bottles, Wheat thins, Cheez-its, Macaroni and Cheese, Bags of candy, Tuna, Chips, Cookies, Hot Chocolate, Cans of Punch

Lab Project #4

Purpose: Apply stopwatch time study, rating of workers and computation of time standards.

1. Each group will do time studies at the six stations.
2. Describe the activity process. Each worker does the activity using the same process.
3. At least two students will do the activity at the station twice, at least two will time the worker.
4. The first time the worker will do that activity at normal pace, approximately 100%.
5. The second time the worker will do the activity at a different pace; the worker selects the pace, slower or faster, but does not tell the timers until after completion.
6. Before disclosure, the timers will rate the worker.
7. After the activity is rated and completed, the worker will tell the timers the intended pace. Record the time and both ratings.
8. Calculate the time standard using a 15% allowance and the rating estimated by the timers.
9. Calculate the mean and the standard deviation of standard times for each worker. Calculate a final time standard as the mean of all the standard times for all workers time studied.
10. Write a report to present your data and analysis with a conclusion section.

Stations:

Sorting Cards
Sorting Legos
Collating papers and placing a paper clip on papers.
Tool Use – on bolt and washer assembly
Dealing the game of Solitaire
Counting out 40 pieces of pasta, 3 times and placing in 3 plastic bags

Write a report on this lab, one per group:

- Purpose of the lab
- Description of lab activities
- Data and Results
- Analysis of Data and Results
- Conclusion – discuss the difference between your rating of pace and what the worker thought his pace was. What are the difficulties in rating workers? How would you improve the process of time study? Any suggestions**?**

Lab Project # 9
Queuing

Purpose: Observe, measure and study simulated queueing systems. Compare mathematical model results to data collected on site at the queueing systems.

Introduction:

All arrivals will be assumed to follow a Poisson distribution. We will select a mean time, then you are to "randomize" it by not arriving exactly then, but some time before or after.

Service times will be done three ways: exponential (again approximated), arbitrary, with a large variance, and constant. The mean service time is 60 per hour, or 1 minute.

Tasks:

A customer needs to arrive at the station according to the arrival rate of 50 per hour. The arrival czars for the three stations will send a customer to the station as described above. The server will then service the customer according to one of the three ways:

> Exponential: The server will deal cards to the customer starting face down, holding the deck in one hand. Deal them into two piles, on one service, sort them into red and black, next service sort them into piles of spades and hearts and clubs and diamonds. Do it slowly enough to average 1 minute each time.
>
> Arbitrary: Deal cards out like above, only sometimes shuffle them, or sort by the four suits or sort the cards in various ways to add variation to the service time.
>
> Constant: using your stopwatch, take exactly 1 minute for every customer.

Observers will be at each station. They will be recording time in queue, time in system and count number in line and number in system frequently (every few minutes).

Results:

First compute the following quantities for each of the 3 systems using the formulas from your textbook. (For arbitrary service the standard deviation is .0333333 hours):

Time in queue	Time in the system
Number in queue	Number in the system

Then compare these results to the observed results. What are the differences and where do they occur? Which system seems to give the best performance according to our four measures?

What have you learned about queueing systems? Describe the worst queueing system you have experienced.

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Biographic Information

Susan Freeman is an Associate Academic Specialist in the College Of Engineering at Northeastern University. As full-time teaching faculty, most of her teaching load consists of first-year courses in Engineering Design and Engineering Problem Solving with Computation using C++ and Matlab. She has a BS, MS and PhD in Industrial Engineering from Northeastern University and has been teaching in the Mechanical and Industrial Engineering Department for 15 years, some of these courses are Introduction to Industrial Engineering, Engineering Economy, Stochastic Modeling and Facilities Design. Before coming to Northeastern, Susan worked at Eastman Kodak Company for 9 years as an IE.