

# Empty-Handed Demonstrations for Engineers: Think Inside the Box

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## Abstract

Recently there has been much emphasis on the inclusion of technology to improve student learning in engineering and this has proven to be very effective in a variety of engineering courses. The objective of this paper is to supplement technology-based education by teaching fundamental concepts using "empty-handed" demonstrations. This instructive technique is defined as one that is accomplished by using whatever is typically available in or near traditional classrooms and by simulating concepts with students and/or faculty as system components. The defining feature of this strategy is that it does not require special equipment or software to clarify fundamental engineering concepts. Empty-handed demonstrations are dynamic, illustrative and interactive, and increase course effectiveness. Forms of active learning that engage the students beyond lecture have been shown to have lasting value in the students' memory (Bransford et al., 2000; Felder & Brent, 2003). Our ambition is to generate a conference session to demonstrate, share, compile, and catalog some of these no-tech teaching tools. Our secondary objective is to stimulate engineering educators to think "inside the box" of the classroom and realize that, with some ingenuity, the world around us is replete with modeling and teaching opportunities. This paper provides several examples of empty-handed demos from a variety of engineering disciplines describing the goals, materials and set up, implementation strategies, and the inspiration and lessons for each demonstration.

## Introduction

Much of the classic learning model is about the acquisition of knowledge and its subsequent application. Effective education provides a means for students to absorb and comprehend relevant information so that they can retain and apply that knowledge. The undisputed fundamental components of engineering education are those that are described in textbooks and those that we, as professors, introduce in our lectures and labs. Sometimes having the students read books and listen to lectures is not enough and thus greater depth and challenge must be provided in their education. Depth of understanding has often been provided by encouraging the students to become personally involved in activities that simulate or mirror the circumstances under discussion. This teaching strategy is similar to techniques of interactive engagement (IE) referred to by Hake (1998). Hake maintains that "the use of IE strategies can increase course effectiveness beyond that obtained with traditional methods."

Strategies of active engagement and active learning, while beneficial in their instructive qualities, can be prohibitive unless they efficiently and effectively carried out, with minimal cost to the engineering program. It is preferable to keep them simple in content to avoid the educational messages being lost in the complexity of the set up. An ideal example of this is the human histogram created in an engineering statistics course at the University of Oklahoma to illustrate birthday distributions and related probability measures (Rhoads, 2004). The students physically line up in categories to form and observe the birthday frequency distribution. They use their own birth date data to calculate the relevant probability measures and confirm established equations related to these statistics.

In this paper, we consider situations -like the statistics example above- that have been found to be problematic for student comprehension and provide examples of activities that have been successfully applied to illustrate course topics. We shown how everyday examples in life and ordinary materials in our immediate surroundings can be used to illustrate broad engineering principles and inspire engineering ingenuity. They are described as "empty-handed demos" because each exercise described requires no or minimal materials to conduct and none requires technology. Furthermore, the professor remains virtually empty-handed throughout the presentations, primarily driving and supervising the activity and allowing the students' participation, observations, and experiences to catalyze the learning process.

## General Engineering Programming: Argument-Passing Mechanisms

Students often have difficulty understanding and remembering the differences between the two primary argument (parameter) passing mechanisms, namely call-by-value and call-by-reference. This demo illustrates the merits and drawbacks of the two methods, visually leading the students to an informed decision as to which mechanism is appropriate for programming situations they may confront.

*Materials and Set Up:* Three students and some paper are required. Colored file folders and brightly colored paper enhance the illustrative value of the demonstration. The student participants stand at the front of the classroom, representing coding constructs, such as functions, variables, and memory locations (addresses). The professor directs the logical flow of the activity, emulating the flow of logic through the main function of a C++ program. The function students then theoretically “works” on the other student’s variables to generate a result from the function’s operations.

The call-by-value method in Figure 1a generates a copy of the relevant variable and allows the function perform its task on the copy, thus preserving the original variable. Simulation of this mechanism is accomplished with three students: one student with a file folder containing a paper which represents the original variable, a second student to hold a second sheet of paper (representing a copy of the original variable), and a third student and folder representing a function. The function is the more dynamic component of this demo and physically moves where the professor (main function) sends the student to theoretically work with the *copy* of the original variable and return a result from the function folder. This demonstration shows that while it takes extra resources – person and paper – to use the call-by-value method, the original piece of paper (the variable) remains safe and untouched in the original folder with the first student, and only the copy is affected by the function.

Following the demonstration of the call-by-value method, the contrast is then made with the call-by-reference mechanism, shown in Figure 1b. With this mechanism, the function goes directly to work at the location, or address, of the original variable precluding the need for a copy. This type of mechanism saves memory and takes only two volunteers to illustrate. The “function volunteer” works directly on the paper held by the variable holder. In this demonstration, the class sees that the original variable is subject to modification because the function has direct access to the variable and no back-up copy is made; therefore, the original value can be lost or overwritten. Students are able to physically observe the advantages of each approach and thus make an informed decision as to which type of function is appropriate for the circumstances in their particular problem-solving issue. Naturally, the professor functions as the main program which is why he or she is charged with orchestrating the execution of each type of mechanism.

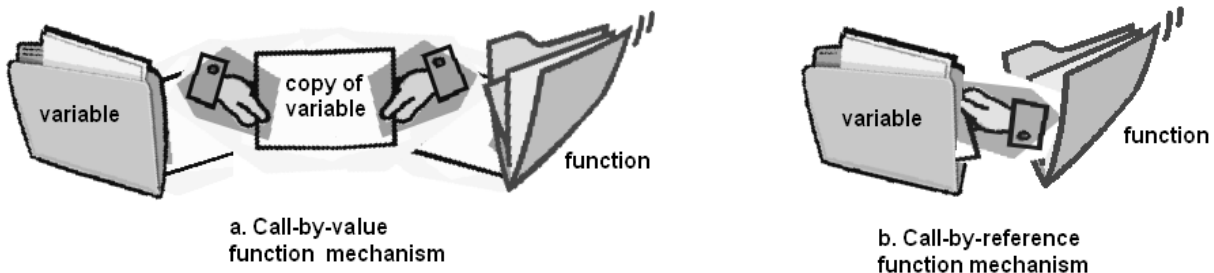


Figure 1. Two function mechanisms in C++: a. Call-by-value makes a copy of the original variable. b. Call-by-reference works directly on the original variable at its address. Students act as components.

### Reference:

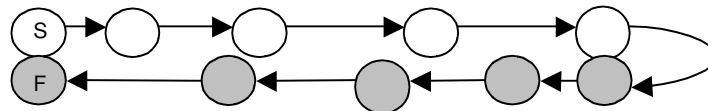
Johnsonbaugh, R. & Kalin, M. *Applications Programming in C++*, NJ: Prentice Hall, 1999.

## Electrical and Computer Engineering: Low-Pass Filter

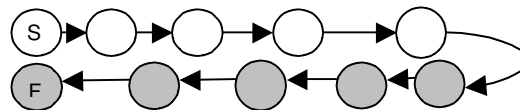
This activity demonstrates the frequency response of a low-pass filter. This is designed to help electrical and computer engineering students understand this transmission option as a considered signal-passage mechanism.

*Materials and Set Up:* A volunteer student who is in good physical shape is selected. The student is asked to start near the center (front) of the classroom, move to the right, and return to the starting point, at a measured pace, while the distance traveled from the center is observed by the class. Several frequencies are represented in Figure 2 below. The instructor counts from one to five and the student reverses direction when the count reaches five. The pace or rapidity of counting (frequency) is gradually increased until the distance traveled shrinks to nothing and the student remains virtually stationary. The traversed distance represents the output of the system at a particular frequency. The students are able to visualize the cycle more readily by observing the subject's movement and are better able to understand the relationship between the frequency and distance traversed. This demonstration leads to a discussion of how a filter may pass relatively low frequency components in the signal but stops the high frequency components.

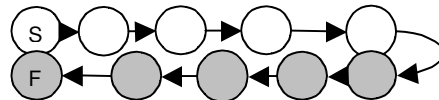
First Pass - Slow counting: "One-hundred-thousand-one, one-hundred-thousand-two, ... "



Second Pass - Faster counting: "One-thousand-one, one-thousand-two, ... "



Third Pass - Very rapid counting: "One-O-one, one-O-two, ... "



Fourth Pass - Most rapid counting: "One, two, ... "

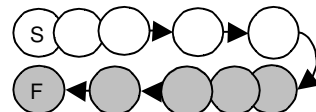


Figure 2. Illustration of student traveling to represent signal frequencies, S=start, F=finish in cycle.

### References:

Schaumann, R. & Van Valkenburg, M.E. *Design of Analog Filters*. England: Oxford University Press, 2001.

Pozar, D.M. *Microwave Engineering, 2<sup>nd</sup> Edition*. New York, NY: Wiley, 2001.

## Computer Networks: Aloha, Slotted Aloha, Ethernet, Wireless and Probability

When teaching computer networks, wireless networks, and principles of probability, the students need to understand the various broadcast methods to be able assess their applicability and suitability to future transmission problems posed to them. One such transmission type is slotted Aloha, a broadcast method that is similar to the basic Aloha method and Ethernet-type networks. In the basic Aloha transmission protocol nodes will send transmissions whenever they have data to broadcast. At this time, it will send a packet and then check to see if it was successfully transmitted. There is no coordination among the transmitting nodes in the Aloha protocol, which makes it problematic, particularly when used with shared channels with multiple users. Between transmissions, a random time period elapses and then retransmission occurs, but there is still no guarantee or known probability of a successful transmission occurring. The slotted Aloha broadcast method is characterized by transmission of packets in discrete transmission slots. Time is divided into equal intervals and a newly arriving transmission packet will be sent at the beginning of the next time slot after its arrival. If a collision with a competing transmission packet occurs, then the source retransmits the packet at the beginning of subsequent time slots. See Figure 3 for the schematic of nodes and time slots.

Given  $N$  users sharing a resource (channel, link) and time divided into known discrete intervals, or slots. Each user has a probability  $P$  of trying to transmit in a slot. The students are asked:

- What is the probability of a successful transmission in a slot?
- What is the probability of a collision in a slot  $P(C)$ ?
- What is the probability that the resource encounters an idle or empty channel  $P(E)$ ?
- What value of  $P$  maximizes the probability of a successful transmission  $P(S)$ ?

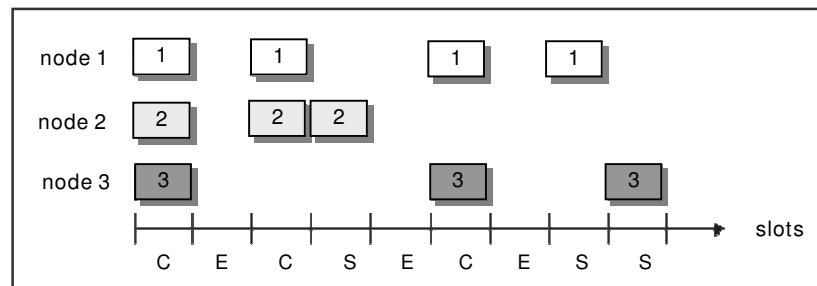


Figure 3. Slotted Aloha outcomes: Collision=C, Empty=E, Success=S

*Set Up:* This demo requires several students ( $N$ ) to represent nodes attempting to send data. In the class demonstration, we ask for student volunteers to simulate the competing users and one to be the timekeeper, acting like a human metronome by tapping the desk every five seconds to indicate the beginning of a slot. For this timekeeping task, you probably would prefer to appoint a drummer, but you can settle for any musician or a student using a watch. Next, ask the  $N$  students to randomly begin singing a verse from their favorite song, within five seconds from the beginning of a slot. If two or more students begin to sing within the five seconds, then the instructor should also sing, either out of tune or generate an auditory signal, indicating a collision. This signal directs the “colliding” singers to become silent until the beginning of the next slot. If only one student sings, then the student captures the channel and sings until the end of the slot. If no one begins in five seconds, then it is declared an idle channel. The process is repeated a few times to demonstrate the nature of the collisions, successful transmissions, and occasions when there is an idle channel when using this transmission method. It is recommended to begin with a user set of  $N=2$  and then move to larger  $N$  values to more effectively illustrate the dynamics of the transmission display.

### References:

Leon-Garcia, A. & Widjaja, I. *Communication Networks: Fundamental Concepts and Key Architectures*. New York, NY: McGraw-Hill, 2000.

Tannenbaum, A.S. *Computer Networks*. Englewood Cliffs, NJ: Prentice Hall, 1981.

## Computer Networks: Election Algorithms in Distributed Systems

In probability and distributed systems courses, students examine the process by which a leader, or process coordinator, is elected at the startup of a system, or when an existing leader fails. Election algorithms are often used to demonstrate the process for selecting a leader and determining the minimum, maximum, and average number of messages required to be sent in order to locate or select the leader. It is often difficult for the students to understand how each of these algorithms function. Demonstration of some of these algorithms generates a visual comparison and helps the students to understand the process involved in each algorithm and better comprehend transmission protocols

One algorithm that can be displayed using the empty-handed method is the ring algorithm, and this is shown as the Distributed Election Algorithm in Figure 4. In the ring algorithm, a node compares itself to its neighbor in the ring and then sends this comparison as a message to the neighboring node. The algorithm helps decide if the subject node is elected or not, through the comparisons of node IDs around the ring.

*Set up:* This algorithm requires several volunteer students (up to 8-10) to represent candidates for the leadership position in question; they are known as nodes for the demonstration. In this activity, you may make multiple copies of the algorithm, number each copy with an integer, which then becomes the node identity (ID) of the student ( $N_j$ ), and distribute one copy to each student. However, if paper materials are not prepared in advance, the algorithm can be displayed on the board and students are then instructed to select a number, taking care not to duplicate ID numbers. In either case, the students then form circles (rings) and proceed to execute the algorithm, which begins when one or more students decide(s) to send a message to their neighbor. Each student responds to arriving messages, "TEST ( $N_i$ )", and records the highest node value seen in the set,  $M_j$ . In the ring algorithm, a node compares itself to the one it sends the message to which is a neighbor in the ring and the algorithm decides whether it is elected or not, through the comparisons of node IDs around the ring.

A comparison can be made to other algorithms by asking the students to try several scenarios; for example, using only one student to start the algorithm as shown in Figure 5, and then having two or more students initiate the process.

### Finding the Leader Distributed Algorithm

Response of node  $j$  to TEST ( $N_i$ )

If ( $N_i = N_j$ ) STOP. /\*  $N_i$  is the leader. \*/

If ( $N_i > M_j$ ) send TEST ( $N_i$ ) on other edge to neighboring node.

$M_j = N_i$  /\*Assign to  $M_j$  the value of  $N_i$  \*/

else

Choose randomly between neighbors and send TEST ( $N_j$ ) /\*TEST  $N_i$  is terminated\*/

Node  $j$  data structure

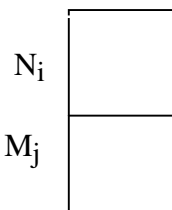


Figure 4. Distributed Election Algorithm.

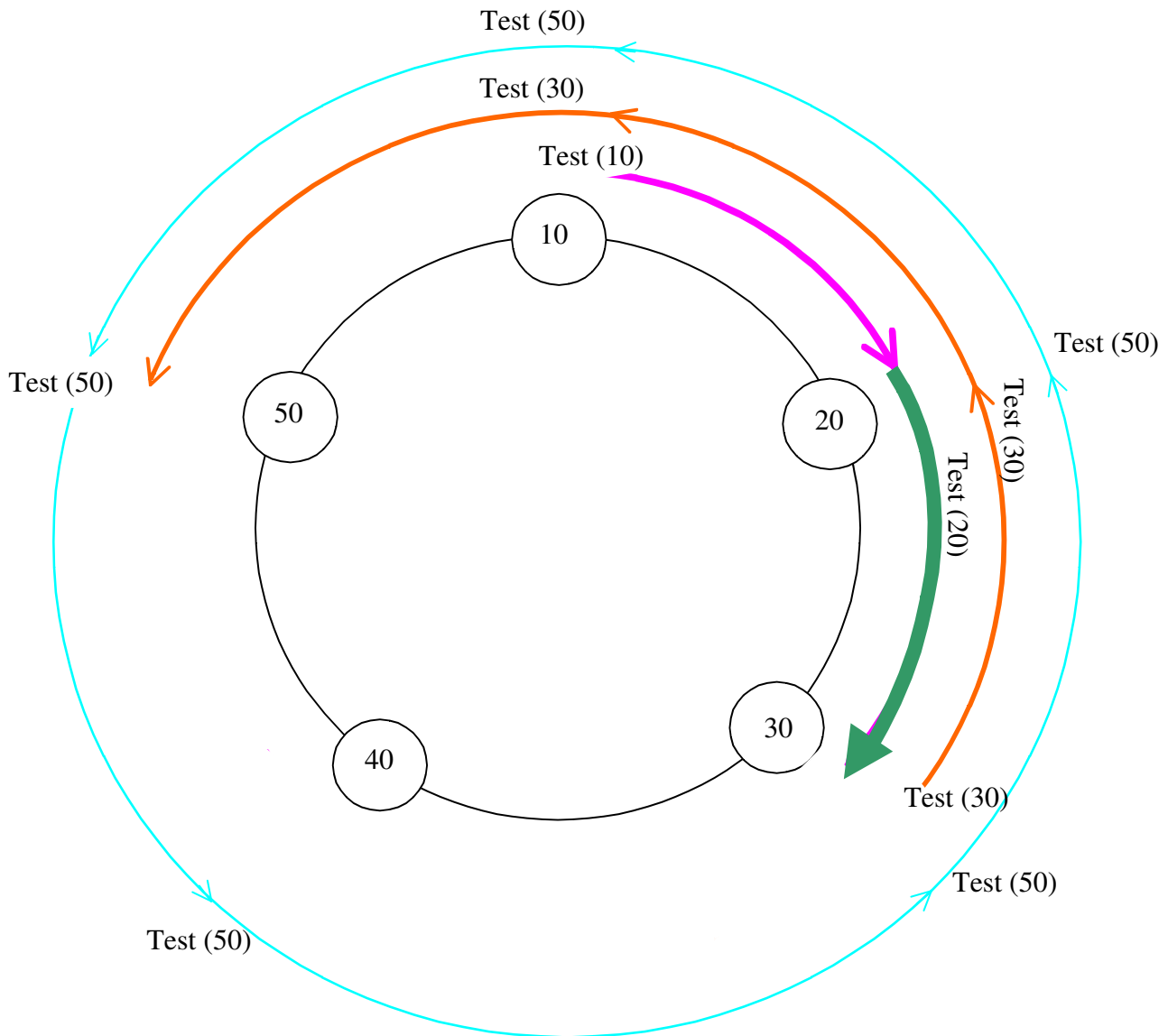


Figure 5. Node 10 starts the election algorithm. All other nodes are awakened by test messages.

In a similar way, the Bully algorithm could also be demonstrated. This occurs when a node sends a message to all higher nodes, if no one responds, it elects itself and sends the message that it is the winner, and thus the leader.

#### References:

Aburdene, M.F. "Distributed Algorithm for Extrema-Finding in Circular Configuration of Processors". *Computers and Operations Research*, 2(1), 87-89, 1985.

Aburdene, M.F. "Distributed Algorithm for Extrema-Finding in Circular Configuration of Processors". *Proceedings of 1982 IEEE International Large Scale Systems Symposium*, October 11-13, Virginia Beach, VA., 269-271, 1982.

Tannebaum, A.S. & van Steen, M. *Distributed Systems: Principles and Paradigms*. Upper Saddle River, NJ: Prentice Hall, 2002.

## Industrial Engineering: Digital Simulation - Distinguishing ATTRIBUTES and VARIABLES

In digital simulation techniques, the flow of entities through a system is monitored in order to make operational decisions. This is accomplished by coding in a selected simulation language. In simulation model development, it is essential for students to distinguish between ATTRIBUTES, which are specific characteristics of entities and VARIABLES, which are more general to the simulation system. This concept is initially confusing for new students, so the following in-class activity was developed to illustrate and clarify the distinction.

Using a recycling simulation example, an arriving recycling truck on a collection route is an entity, as seen in Figure 6. The truck entity has several attributes that affect the simulation. Some of these attributes could be the number of on-board personnel, its potential weight capacity, potential volume capacity prior to collection time at the start of the route, and delivery weight and delivery volume at the end of the route. Each of these properties are specific to the subject entity. Even if other trucks possess some of the same properties, not all share the same levels of these features. Thus they are ATTRIBUTES with assigned values that are exclusive to each entity. On the other hand, system VARIABLES are general and global and their values do not necessarily apply to any particular entity or truck. Examples are system start time, system time at any given point, number of recycling trucks in the fleet, number of runs completed, the average time per recycling route, the truck with the biggest load, and the truck with the highest or lowest remaining capacity.

*Materials and Set up:* Chalk or white board, colored paper, markers, and binder clips (optional). The professor as the Moderator drives the simulation. Attributes of the entities, such as start time or load weight, are recorded on the pieces of paper. The Moderator assigns these attributes to the entities as they move through the system by clipping the paper, with the defined value, to them. The Moderator also determines when state-changing events occur or values are need to be updated. Several students are assigned to be truck entities that move through the system possessing or collecting ATTRIBUTES. Entities accumulate ATTRIBUTES when the Moderator attaches the paper with the attribute value, which remains with them throughout the simulation, although its value may change. A different student is assigned to be the System Reporter at the front of the room. The System Reporter is responsible for keeping track of the system VARIABLES as directed by the Moderator.

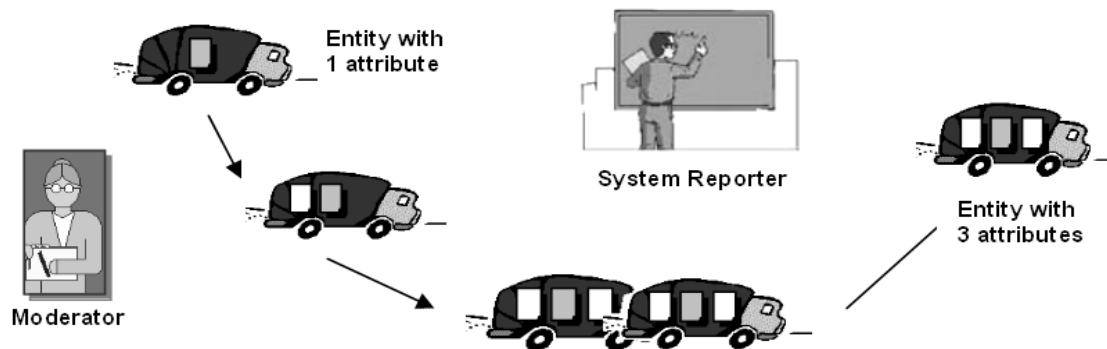


Figure 6. Configuration for Moderator running the simulation system, student/entities with 'attached' ATTRIBUTES, and System Monitor keeping track of global VARIABLES.

This activity physically illustrates that ATTRIBUTES associated with each of the individual entities and apply only to them. In contrast, the VARIABLES, such as current time, queue length, and time spent in the operation, apply to the system in general and are never recorded on the entities. Instead, the variables are separately maintained by the program through the records kept by the System Reporter. This exercise is often referred to when questions about attributes and system variables arise. Fewer errors in property assignments occur after this in-class activity.

*Reference:* Kelton, W.D., Sadowski, R., & Sturrock, D. *Simulation with Arena, 3<sup>rd</sup> Edition*. Boston: McGraw-Hill, 2004.

## Mechanical Engineering: Gear Interaction

This activity helps to illustrate the dependent interactions among rotating gears. Mechanical engineering students are expected to be able to predict the ultimate direction of the rotation of a component within a series of interlocking gears. Successfully and reliably predicting directional rotation in interlocking components is difficult to do at first because it is initially hard to imagine. This skill is best taught by providing a visual simulation of working gears to provide a solid basis for the students' calculations.

*Set Up:* Several students (usually up to 8 in total) are asked to simulate the action of gear components, but first begin with two participants. Students serving as gears, stand with hands clasped and arms akimbo. They must be close enough to one another for their elbows to make contact, as shown in Figure 7. The central gear (Student 1) slowly spins, subsequently contacting the next gear (Student 2). Gear 2 will respond by spinning slowly in the appropriate direction to illustrate the standard gear interaction. Directional terminology is established as clockwise and counterclockwise as viewed from above.

The real fun begins when gears are added to Gear 2 and on the other side of Gear 1 and additional corresponding offshoots are also created. Figure 8 below depicts this scenario. All gear-students must still be close enough to make elbow contact and are expected to respond by turning in accordance with standard gear dynamics. Non-participating students are asked to quickly predict directions of terminal gears.

There is also the option of adding complementary components in order to elicit the effect of multiple-gear contact without the gears jamming. Other gear meshes, such as gear trains, wheel-and-pinion, and rack-and-pinion gear assemblies, can be illustrated with this method. The value of visualization is significant in this case because the students become adept at generating images of how the gears work and consequently rely less on memorizing gearing principles and more on their visualized understanding of gear-related dynamics. This can also help with more advanced gearing systems, such as bevel gears, worm wheels, helical gears, and external and internal face-cut gears, although they are not as easily demonstrated.

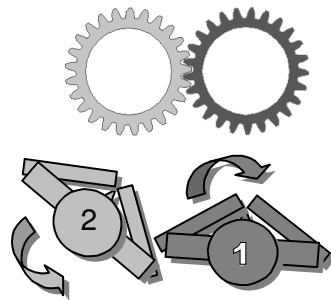


Figure 7. Students emulating a pair of spur gears in mesh, view from above.

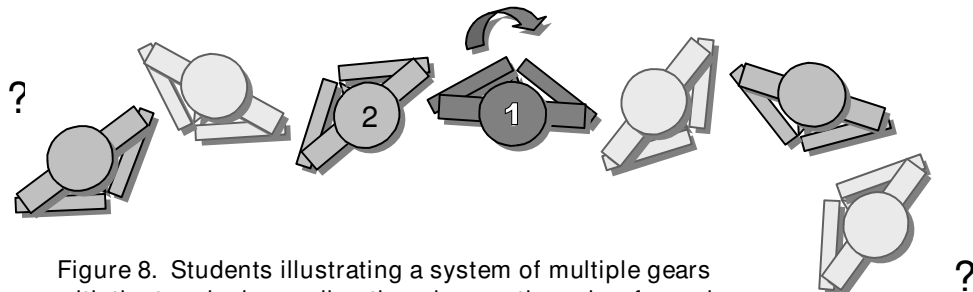


Figure 8. Students illustrating a system of multiple gears with the terminal gear directions in question, view from above.

### Reference:

Buckingham, E. & Buckingham, E.K.. *Manual of Gear Design, Volumes 1-3*, Industrial Press, 1999.



## Civil Engineering: Managing a Four-way Intersection

Part of the civil engineering curriculum requires students to analyze traffic problems and propose solutions to each situation. In-class activities can demonstrate the transportation issues that arise from the application of various traffic control methods, such as two-way and four-way stops, and timed traffic lights and enable the students to compare the effect of each suggested solution. When studying traffic management problems, 4-way intersections provide a standard and common situation requiring a reasoned solution. It is simple enough for the students to quickly understand the scenario and has sufficient complexity to foster detailed thought promotion when analyzing the variety of possible solutions.

*Materials and Set Up:* Watch, colored paper (to serve as traffic control devices), pieces of scrap paper containing written vehicle-activity instructions, such as turn left, go straight, jump your turn, etc. To make the intersection, clear the tables and make a cross aisle. The vehicle-activity instructions and traffic control devices, such as stop signs or traffic lights, are placed at the corner of each table, as seen in Figure 9 below. Students represent vehicles and are instructed to make their way through the intersection in an efficient and orderly fashion. Each student vehicle will encounter either a stop sign or a traffic light, depending on the system under investigation. The students are divided into 4 unequal groups to represent traffic with varying arrival streams. The goal is to compare the 4-way stop sign intersection to a timed traffic light to illustrate system behavior.

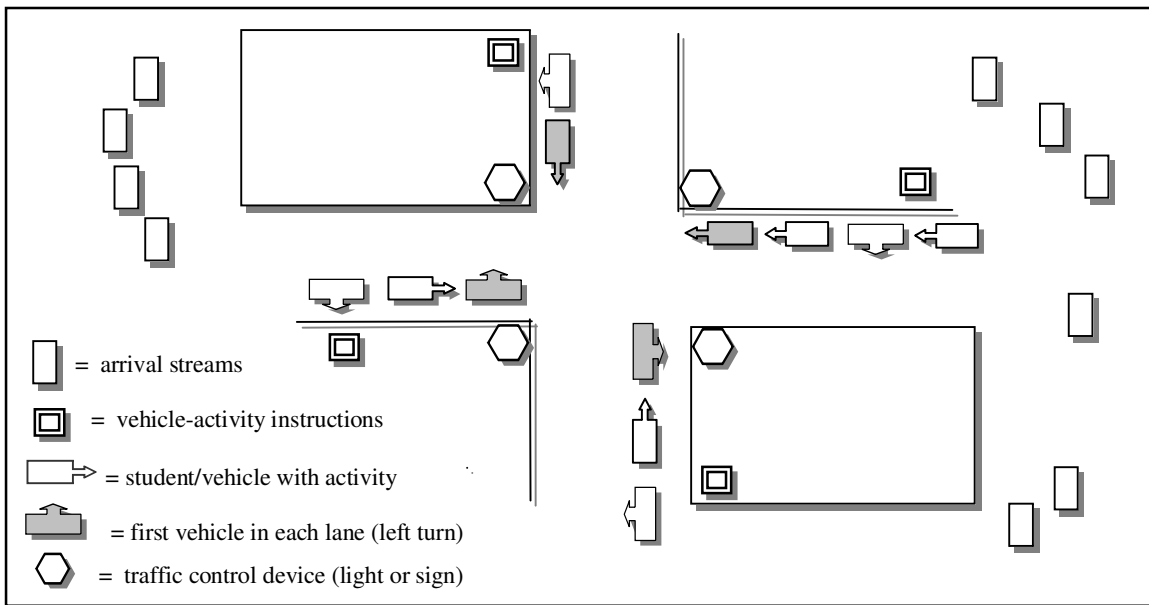


Figure 9. Configuration for 4-way intersection traffic exercise in the classroom.

Initially, we begin with a 4-way stop simulation. The professor sends vehicles from each of the arrival streams to the lanes, allowing only a few cars to accumulate at each stop sign. Students are reminded of the rules of 4-way stop intersections: First-in-first-out in sparse traffic; opposite ways proceed simultaneously when there is a greater concentration of vehicles at opposite intersections; and take turns clockwise around the intersection if all lanes are occupied. The first scenario is conducted with no turns made by any cars and no vehicle-activity slips being used. This is the simplest scenario and should run smoothly.

Next, complexity is added to the 4-way stop system. On each arrival to the intersection, students collect a small slip of paper instructing them as to their vehicle's next maneuver after they arrive to the stop sign. The professor continues to feed the roadways from the arrival streams. Vehicles are to follow the basic four-way rules above, but (1) now some vehicles may turn, according to their vehicle-activity slip and (2) some vehicles are instructed to jump their turn. Students are now asked to observe and later describe the problems created by left-hand turns and vehicles violating the rules of the road by jumping their turn.

In other iterations of this scenario the professor orchestrates a rapid arrival rate, permits multiple vehicles to proceed in thick traffic, and allows for more violations to occur. The same arrangement and scenarios can be done with a two-way stop or blinking yellow and blinking red lights. Clearly, the two-way stop would be the most basic scenario, and the professor may choose to begin with that configuration first.

For the timed traffic light, the only change from the 4-way stop is that the arriving vehicles are expected to obey the traffic lights. A student is appointed the “traffic czar” and is responsible for consistently timing the lights. The class can recommend the phase (or green) time to be used for each direction of the intersection. Try several suggested timing scenarios and observe the outcomes for discussion.

As traffic engineers, we compare the traffic control options, the incidents and collisions, behavioral outcomes, lane congestion, and time or delay in system. Each of these simulations helps us generate discussion points. More data for discussion can be obtained from the activity by measuring various indicators of system effectiveness, such as how many crossings occur in a time period (flow rate), how large queues get, and how long it takes to “clear the system”.

#### *References:*

Garber, N.J. & Hoel, L.A. *Traffic and Highway Engineering*, Brooks Cole/Thompson, 2002.

McShane, W., Roess, R.P., & Prassas, E.S. *Traffic Engineering*. NJ: Prentice Hall, 1998.

Transportation Research Board, *Highway Capacity Manual*, National Research Council, Washington, DC, 1994.

### Industrial, Electrical, Computer, and Civil Engineering: Queuing Theory

The demonstration is intended to illustrate basic queuing theory formulae and applications. Typically, these equations are not readily understood by students and this activity will help them appreciate their foundation and application when solving similar problems. To introduce queuing theory in computer networks, industrial engineering, and operating systems, we often present the M/M/1 queue at equilibrium. Given an arrival rate  $\lambda$  and a service rate  $\mu$ , the average number of customers,  $N$  in the queuing system equals:

$$N = \frac{\lambda}{\mu - \lambda}$$

To compute the average delay  $T$  we can use Little’s formula of  $N = \lambda T$  and solve for instant values of  $T$ .

*Set Up:* To demonstrate this in class, a student, who is wearing a colorful outfit, hat, or shirt is selected. Other students are then asked to volunteer to be part of the demo. Include at least one student who is wearing a digital watch to be the timekeeper. To begin the demo, the students line up outside of the class, with the colorfully dressed student being second or third in line. The students outside the room are then asked to move into the room and walk past the instructor. By engaging some of the students in short conversations, the instructor causes the time  $\mu$  it takes for the students to pass by to vary. This simulates an average service time:

$$\frac{1}{\mu}$$

The timekeeper is asked to start the clock when the colorfully dressed student enters the room and make note of the elapsed time  $T$  when that student passes the instructor. At this point, the timekeeper instructs everyone to freeze. The number of students between the door and the instructor is then counted and recorded. That value is used to represent the value of  $N$ . Since we know the arrival rate  $\lambda$ , the class can conclude that  $N = \lambda T$  and obtain the common equation for the calculated delay for the sequence.

$$T = \frac{1}{\mu - \lambda}$$

*Reference:* Tannenbaum, A.S. *Computer Networks*. Englewood Cliffs, NJ: Prentice Hall, 1981.

## Environmental Engineering: Cleaning up Oil Spills - Thinking Creatively

This demonstration is designed to have the students engage in creative thinking to find ways to solve an environmental engineering problem, specifically cleaning up or containing a contaminated substance in an effective and timely fashion.

*Materials and Set Up:* Strips of toilet paper and water will be used; optional are a spray bottle and paper towels or napkins. Toilet paper is spread out on a table and thoroughly moistened with water. The class is commissioned to work in teams to devise a plan to remove the remnants without touching the paper. They must conceive of and attempt one method in the classroom, and then generate several alternative methods. The alternative solution plans may involve (a) a longer time span, (b) materials outside the room, and (c) chemicals, mixtures, tools and interventions that alter the properties or state of the original material, but do not necessarily need to be implemented in the classroom demonstration.

We chose toilet paper to represent the contaminant because it possesses several unique properties, the most attractive of which is its ready availability at minimal cost. In addition –and more specifically related to this demo– it is designed to disintegrate when wet, it sticks and clings to surfaces, and it cannot be picked up in one piece without falling apart. Also, it is further able to simulate the action of a contaminant because when it dries it changes its form slightly. Finally, it could be set on fire (theoretically). Alternatively, if the professor decides to further relax the “empty-handed” policy, a few drops of vegetable oil or similar substance can be added to a container of water to more closely emulate an oil spill. Both alternative ingredients can be easily obtained.

Students may not initially be aware that this solution-generation demo is designed to be analogous to an oil spill and that we are encouraging them to devise several innovative ways to safely and efficiently clean up and contain the offending substance. Having them brainstorm methods to solve the problem and try to clean up the substance with whatever is available to them will illustrate the difficulty created by oil spillage.

Examples of other solution alternatives that may be further developed in discussions after the demonstration may include suggestions to scrape the substance, (analogous to the boom technique) set it on fire, (as is done for some oil spills) find a substance that will react with the material to make it easier to contain and remove (like elastol or ecospheres), or identify an organism that can consume the material. These alternatives need not be all be demonstrated themselves, but the discussion should inspire this level of creativity.

## Environmental Engineering: Waste Management - A Recycling Demo

The plan for this longer-term demonstration is to illustrate the value of recycling – and the burden of accumulated refuse through a physical example. As often occurs in many situations in life, the sheer magnitude or scale of an object or event is not fully appreciated until one can personally witness it.

*Materials and Set-up:* Three dark trash bags are required for each participant and an optional weighing device. A set of three bags is allocated to each student taking part in this exercise. As this activity takes place over the course of a week, it may be necessary to offer extra credit to any student volunteering to accept this assignment. At least three students should be used for this demo.

The first exercise is to have all non-participants estimate the average weight and volume of trash that will be accumulated per student; this estimation can include a guess for total trash and a division for recyclable and non-recyclable products. Participating students are then requested to collect all of their trash (except garbage) for a week. Clean recyclable materials such as paper, plastic, and glass, are placed in one bag, and non-recyclable trash is placed in the second bag. The participants are then requested to weigh each bag prior to coming to class on the day of demonstration. Both bags are then placed inside the third bag and brought to class on demo day.

In the class presentation, students will physically (1) see how much trash a person can amass in a week's time, (2) feel the weight of the materials discarded, (3) discern the magnitude of savings in weight, volume, and processing by setting aside recyclables, and (4) ascertain how accurate their initial estimations were. The additional embedded lesson in this demo is to compare our abilities of projection and approximation on several levels: *a priori* for the accumulation estimate, then for the psychometric values on estimates of volume, and finally for weight. It is compelling for the students to experience first-hand the magnitude of a prevalent condition that is often invisible to them.

### Environmental Engineering: Acid Rain - How Effective is Attenuation Management?

This demonstration should motivate environmental engineers to prevent acid rain, toxin initiation, and contaminant dumping and its effects at the source. It also stimulates students to consider creative and feasible resolution methods. This demo illustrates how difficult it is to dilute a toxin once it has been introduced to a contained solution.

*Materials and Set Up:* Two clear containers containing water (one half full or less, the other may remain full), and a few ounces of coffee or cola, to serve as the contaminant, are all that are needed. A clear 2-liter bottle is best to use for the dilution vessel as it holds more fluid. To illustrate the powerful effects of contamination (after your oil spill demo), set up the half-full water bottle and the full bottle of water in clear view. Pour a small amount (an ounce) of the coffee into the partially-fully clear water to represent a toxin or pollutant. Then you may begin your efforts at attenuation treatment by adding more and more water by pouring from the full water bottle into the contaminated solution.

It very soon becomes evident that dilution management of contaminated matter is virtually futile in most circumstances. The first lesson, therefore, is clearly prevention. The second element of the lesson is for the students to suggest additional methods for managing the situation after contamination has begun, so that the situation does not become worse and/or it is contained. "Solution" alternatives lead to a discussion of treatments such as chemical neutralization, system flushing and filtration, biological methods such as organisms, and diversion, transport, or removal of the offending substance. The discussion should also focus on their applicability to real world problems. Finally, this is a good opportunity to introduce the students to decision matrices and their use to aid the process of selecting from among multiple solution methods, each of which will have inherent drawbacks and benefits.

### Environmental Engineering: Pollution - An Air Quality Demo

This lab activity is intended to dispel the clean air myth. Students can readily see the effects of invisible pollutants in a very short period of time. Relevant comparisons can be made among a variety of environments.

*Materials and Set Up:* This only requires several squares of white paper, paper clips or tape, and petroleum jelly or clear lip balm. Students each take one piece of paper divide it into 6 equal-sized pieces. A thin layer of petroleum jelly or lip balm is applied to each piece of paper. The students' commission is to choose three very different locations to place two pieces of paper at a time. These locations could include the classroom, a cafeteria, or an outdoor doorway (that is protected from rain). One piece of each paper pair is left for three days and the other one is left for a couple of weeks. It is hoped that the paper will not be lost or destroyed, so the location must be chosen carefully. Using the paperclip or tape the paper should be attached to the chosen location with the treated side out.

When students bring their samples to class after the appointed time period, it is amazing to see that even after a few days pollutants readily accumulate on the white paper. Comparisons can be made between environments and within environments over time. An interesting activity is for the professor to orchestrate a session for the students to match the physical samples with the corresponding set of locations. The instructor can select these samples carefully to illustrate some of properties of airborne particles and pollutants. This exercise is particularly compelling when the samples are clearly soiled, but came from apparent 'clean' locations.

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### Conclusion

Since much of engineering is understood and illustrated through modeling and examples, we aim to inspire educators to continue to think and teach creatively, no matter how basic or complex the topic. This also involves continually envisioning everything in their ambient environment as potential teaching tools and instructional opportunities.

When the questions arises about whether a professor will be able to cover the syllabus when class time is taken to apply these techniques, Felder and Brent (1999) provide a fitting response: When considering the implementation of active learning in engineering education, they note that “if the objective relates to what the students learn as opposed to what you present, then the goal should not be to cover the syllabus but to *uncover* the most important parts of it.”

In developing such activities it is important to first visualize the different levels of complexity and the variety of scenarios that relate to the topic at hand. The educator’s calling is to then desing the activity to guide the students through each of the stages. Clearly it is important to start with the basics and increase the momentum to include more complex and detailed roles. It is also critical to build on each activity by using the students’ own ingenuity in discussions about the embedded lessons. Far broader strokes can be drawn in class when the picture is not limited by availability and cost of materials or technological requirements. Much more of the complete picture can be seen and appreciated when each concept is separately defined and demonstrated for its own unique qualities or *modus operandi*, and then returned to the full scheme as a whole. Empty-handed demos can help contribute to the masterwork of engineering education.

### Additional References

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*Note: In order to stimulate thinking “inside the box” for a variety of engineering disciplines, concepts, and problems, the ASEE audience will be invited to participate in the demonstrations and contribute additional examples. It is hoped that examples will arise that the authors have not yet seen or tried.*