

A GUIDE TO PARTICIPATORY SIMULATIONS¹ ACTIVITIES

Network-Based Design for Systems Learning in Classrooms

Version 1.0
January 13, 2004

**Walter M. Stroup
& Uri Wilensky**

with

Dor Abrahamson, Matthew Berland, Kate Braden, Brent Collins,
Sarah Davis, Matt Goto, Ed Hazzard, Matt Hellige,
Andy Hurford, Jayun Kim, Geoff Mathews, Meera Pradhan,
Al Schademan, and Seth Tisue

We gratefully acknowledge the ongoing support of the
National Science Foundation and Texas Instruments
in developing these technologies and activities.

These activities and associated models and materials were created as part of two NSF sponsored projects:

INTEGRATED SIMULATION AND MODELING ENVIRONMENT (NSF ROLE #0126227) and PARTICIPATORY
SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. (NSF REC #9814682)

Copyright 1999 by Uri Wilensky & Walter Stroup. Updated 2001, 2002, 2003, 2004. All rights reserved.

Permission to use, modify or redistribute these materials, including the models, activities and documents is hereby granted,
provided that both of the following requirements are followed:

1. this copyright notice is included.
2. this model will not be redistributed for profit without permission from the copyright holders.

Contact the copyright holders for appropriate licenses for redistribution for profit.

- [Introduction](#)
- [Some Top Level Tips](#)
- [Disease](#)
- [Function Activity](#)
- [Gridlock](#)
- [Elevators](#)
- [Regression](#)
- [People Molecules](#)

Introduction

Welcome to the future classroom - a classroom rich in networked information technology. This document is intended to serve as an introduction and guide for teachers to the use of the HubNet technology in the classroom. The HubNet technology is the result of an ongoing effort to design, from the ground up, activities and technologies for group learning situations. In particular, HubNet has been designed to enable classroom "participatory simulations" in which all class members are actively engaged in learning activities mediated through technology.

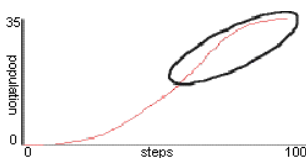
The HubNet design marks a radical departure from a simple repackaging of business-oriented computing solutions for use in schools. Business technologies are typically designed for an individual user working in relative isolation. School technologies, in sharp contrast, should be designed for group use with learners working together in highly interactive ways.

You are about to work with our attempt to embody this functional ideal in a practical way. The six activities presented in this book can be used in your classrooms today to address meaningful curricular objectives. They are intended to illustrate how a range of challenging curricular topics - from understanding functions to making sense of the logistics curve, from understanding the spread of a disease in a population to the optimizing of traffic flow through a city grid, and much, much more - can be approached in engaging and intellectually compelling new ways using participatory simulations. All of the activities have been tested and refined from substantial work in middle schools and high schools from a range of settings (including classes in mathematics, general science, social, urban and environmental studies) in the United States.

What is a Participatory Simulation?



Middle school students interacting using HubNet in a disease participatory simulation learning about the dynamics of the spread of disease (above) and aspects of the emergent logistics (epidemic) curve (below).



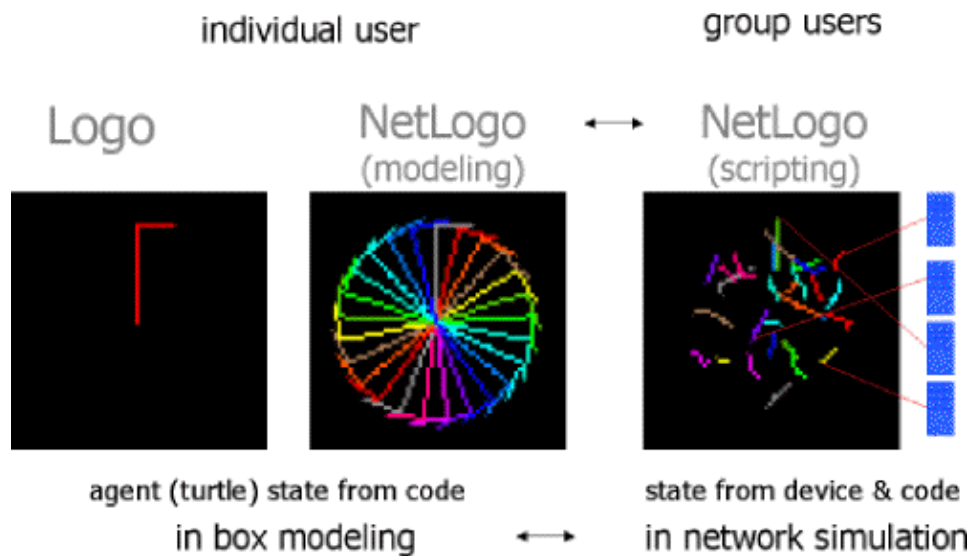
Students engaged in participatory simulations act out the roles of individual elements in a system. Through their actions the behavior of the system as a whole emerges. This emergent behavior of the system and its relation to individual students' actions and strategies then becomes the object of class discussion and analysis.

What is HubNet?

HubNet is the name we have given to a new architecture designed to give students the experience of participating as elements in a simulation of a complex dynamic system. HubNet hardware includes an up-front computer (the "hub") capable of addressing the network of nodes (calculators) and a display capability (e.g., a ViewScreenTM or computer projection system) enabling an entire class to view the simulation. HubNet enables many users at the "Nodes" to control the behavior of individual agents and to view the aggregated results on a joint display. HubNet is designed with the default assumption that the nodes have significant resident functionality (at least that of a programmable graphing calculator). The network layer implements flexible communication protocols that include the ability to upload and download data sets, upload and download programs (e.g., applets), monitor key-presses at the handheld level, support real-time interaction as in network computer games, and form collaborative groups of various sizes (e.g., peer to peer, small groups, and whole-class modes).

What is NetLogo?

Although NetLogo can trace its roots back to the programming language LISP and also to a version of LISP used in super-computing called *LISP (pronounced "star-LISP"), the easiest way of thinking of NetLogo is as a special version of the language LOGO. Logo, as you may know, is a language that enables a user (often a young child) to control a graphical turtle by either typing individual commands like "forward 50," or by writing procedures that do a series of commands. By having a turtle put its pen down, go forward 50 steps, turn right 90 degrees and then go forward 20 steps you can get something like the inverted "L" shown on the left below. Learners can construct models of a wide range of physical and mathematical phenomena using this turtle-controlling language.



In NetLogo the user can create tens, hundreds or even thousands of turtles. If the same commands as those given above for the upside-down "L" are now used in NetLogo, we end up with something like what is shown in the middle image above. Each of the turtles does these commands "for itself" and the wagon wheel image results. (Note that each of the turtles started with a distinct initial orientation (aka "heading") so they wouldn't just be stacked up on top of each other). Like Logo, but in a much more powerful way due to the ability to control multiple turtles, NetLogo can model a wide range of physical, mathematical and even social behaviors.

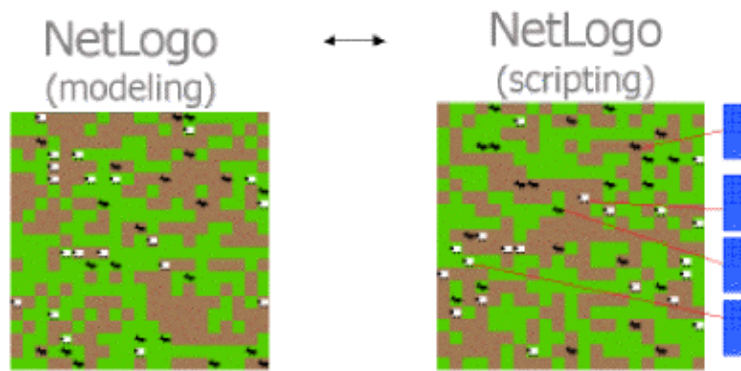
Up until this point, both Logo and NetLogo are thought of as working within a single "box" or running on a single computer. Everything that happens on the screen happens because of commands that happened within that box (e.g. forward 50). In computer speak, the "state" of the turtles is determined completely by either the Logo or NetLogo code, depending on which you are working with.

When NetLogo is hooked up to a network however, some of that control can now come from "outside the box" or outside the single stand-alone computer. In the HubNet system, that outside input can come from calculators or from other devices connected to the network. Each device can control an individual turtle. If all the participants controlling a turtle with their devices put their pens down, and use the arrow keys to wander around, we might end up with an image like the one on the right of the above image. Each user is making his or her own decisions about how to move, and this input is being used by NetLogo to create the group result. The state of the turtles is now determined by a combination of input from the devices, and NetLogo is then doing something with this input. To help keep this use of NetLogo somewhat distinct from the "in the box" use, we speak of the "out of the box" programming as "scripting" and the former "in the box" programming as "modeling."

In addition to having turtles that move over the surface of the screen and interact with each other, NetLogo also has a grid of programmable "patches" that the turtles can walk over and interact with. Patches can be thought of as little cells or rectangles that make up the background of the NetLogo world. Patches can also interact with each other and with turtles. Finally, NetLogo has an "observer" level that can look at what's happening for the whole model and do things like count the number of turtles that are green or the number of patches that are yellow.

The following image shows how NetLogo can work either as a stand-alone modeling language or as a scripting language for creating participatory simulations.

**Has Full capability of Agent-Based Parallel
Modeling Language**



- Breeds (e.g. wolf and sheep - supports any grouping/topology)
 - Agents (and patches) know how to interact
- Can identify (e.g. follow, count, average) any individual or group
 - Full graphing, analysis, sorting, etc.
 - All with minimal, extensible code
 - (AND YES, it does [has LISP roots])

For both the stand-alone ("in the box") model on the left and the possible network activity on the right (the participatory simulation), the rabbits and wolves are two kinds of "turtles." They are programmed to interact differently when a rabbit bumps into a wolf as opposed to when a rabbit bumps into another rabbit. The rabbits and wolves are what are called "breeds" of turtles. In these examples, the grid of patches is used to model grass. The patches - the simulated grass - interact with rabbits differently than they do with wolves. Rabbits can eat the grass, turning it brown. Over time the grass will become green again. A major difference between the stand-alone model on the left and the participatory simulation on the right is related to control. In the stand-alone model illustrated on the left, the rabbits and wolves wander randomly around the screen and this random movement is completely controlled by the NetLogo language. In the participatory simulation illustrated on the right, each individual student uses the calculator to control either a rabbit or a wolf in the participatory simulation. The rules for interaction remain the same (so if a rabbit runs into a wolf, the rabbit dies and the wolf gets more energy). Either the stand-alone model (left) or the participatory simulation (right) can simulate a simple predator-prey ecology.

Both NetLogo modeling and doing participatory simulations with HubNet enable new powerful classroom activities and learning. In this guide, we will focus on the HubNet technology and participatory simulation activities. An advantage of using participatory simulations is that students identify strongly with their roles and, from working together in this embodied way, begin to feel a need to create certain kinds of mathematical or scientific ideas. Closely related to this increasing articulateness is the development of a much deeper and more meaningful understanding of mathematical and scientific ideas. Participatory simulations scaffold deeper engagement with, and understanding of, challenging curricular topics for a wide range of students. Students will develop a significant set of insights from working with participatory simulations. For participatory simulations to work up to their potential however, we have to be ready to support discussion and focused interactivity in our classrooms. The best way to begin to get a feel for how this can work is for us all to jump in together to try out for ourselves what this next generation form of classroom learning is like. Enjoy!

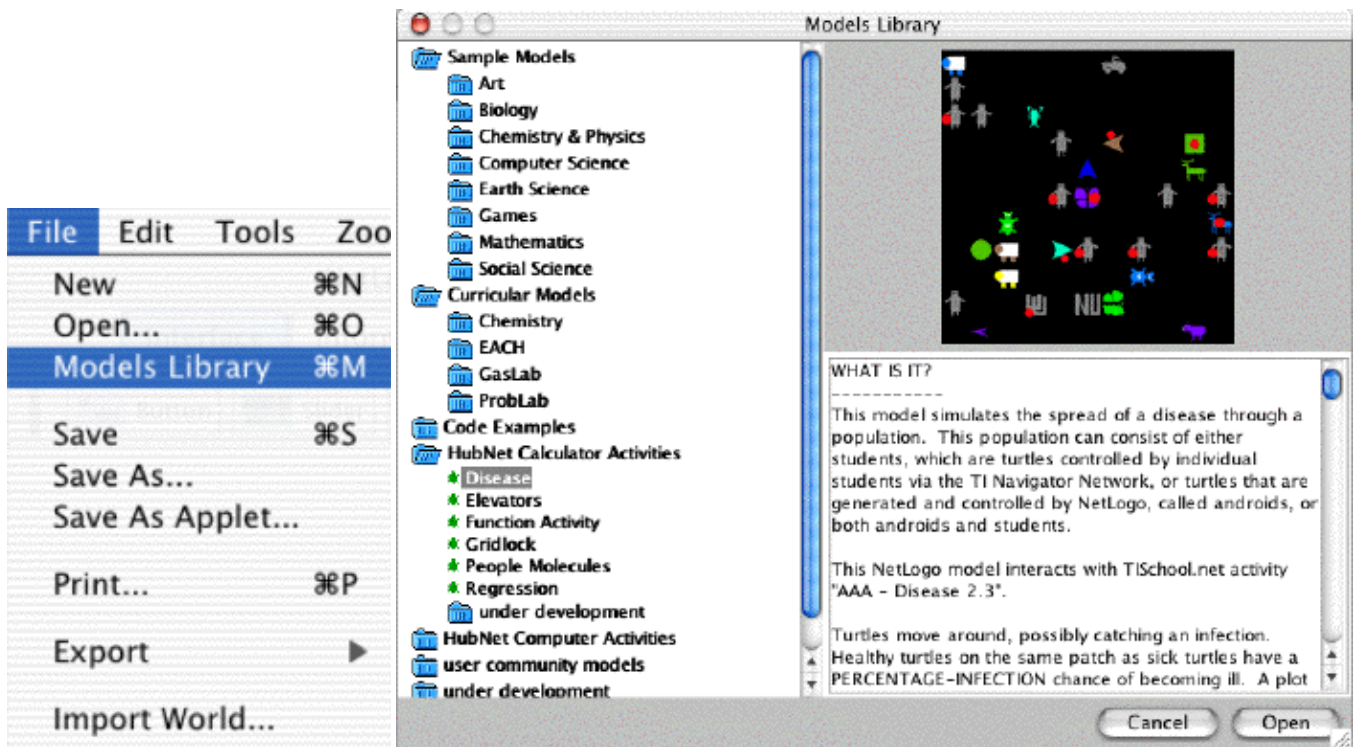
Some Top Level Tips

Start with Something Physical or a Meaningful Example

From motion detectors to rolling dice, from building walls of delta-blocks to working with motion detectors, we have found it is important to begin with some kind of hands-on activity or meaningful example as part of working with a HubNet mediated participatory simulation. HubNet-based learning is an important kind of hands-on, minds-on learning that integrates well with other forms of hands-on, minds-on activities.

Finding the HubNet Models

When you open NetLogo, you can find the HubNet activities in the Models Library that is found in the File menu.



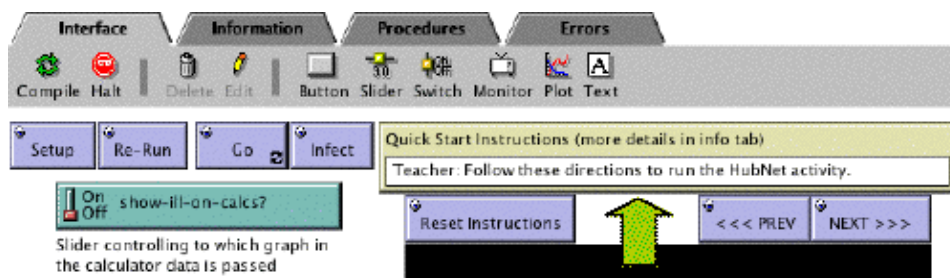
A description of the HubNet activity (or of any of the stand-alone models also found in the library) appears when you click on the title. Double-click to open this activity. Since there are currently two different types of HubNet implemented, be sure to open the folder that refers to the type of HubNet that you wish to run. For instance, if you wish to use Computer HubNet, be sure to open the HubNet Computer Activities.

Where Can I Get NetLogo?

NetLogo can be downloaded for free from <http://ccl.northwestern.edu/netlogo/>.

QuickStart Directions

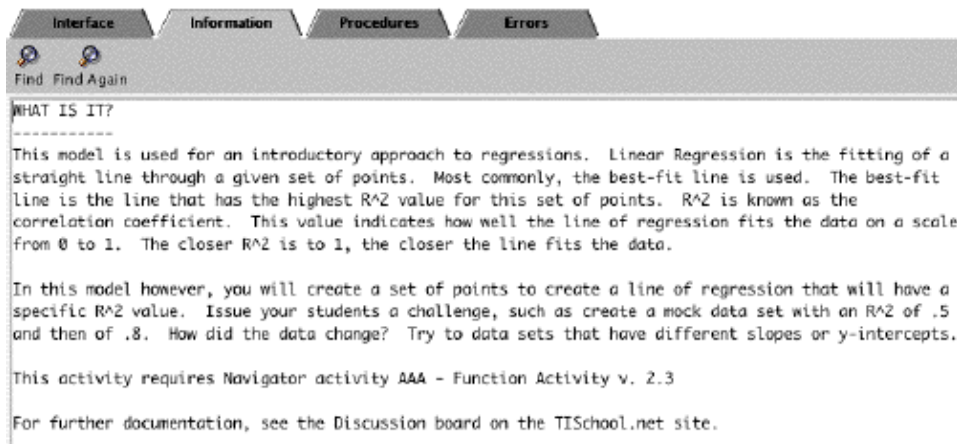
To help you get started and run an activity, we have included QuickStart directions at the top of every HubNet model.



Click the Next or Back button to change the directions. Also, for each activity that follows, we've included a printed version of these directions.

Information Tab

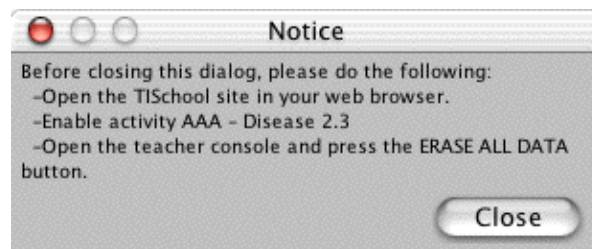
Additional information for each HubNet activity (and also for each model in the library) can be found by clicking on the Information Tab. There is a standardized format for the content of this tab so you can become increasingly adept at finding what you need as you move from model to model.



And as is true for the text of the QuickStart Instructions, for each activity we've printed the Information Tab for your "off line" review.

Opening a Calculator HubNet Activity

When you open a Calculator HubNet model, a dialog will appear to help you get the activity set up properly. This dialog, which looks similar to this,



will tell you which activity to enable on the TISchool website. See below for more information on how to enable an activity on the TISchool website. Then, if this is the first time you are opening a Calculator HubNet model in a particular session of NetLogo, you will be confronted with the TI-Navigator Login dialog.



To run use Calculator HubNet, simply type in the same User ID and Password for the teacher calculator to login to the TI-Navigator system. Make sure that the Host Name box has the IP address of the TI-Navigator server. If you are using the stand-alone TI-Navigator system, the IP address is usually 192.168.110.2. Then press the Login button.

Once you have pressed the Login button in the TI-Navigator Login dialog, NetLogo will connect to the TI-Navigator server allowing NetLogo to know when people to join the activity. You should then follow the instructions for the particular model found in the QuickStart Instructions monitor. Most models will require you to press a forever button, often called GO. You, as the leader, should notify everyone that they may join.

Setup and Re-Run

Each HubNet activity has two buttons.



Setup is what you use when you start a new class or switch activities. Of the two it is the "stronger" command and almost always is accompanied by students having to login (or re-login if you switch activities). Re-Run, in contrast, is what you push after you've done an activity once and you just want to repeat the activity without requiring the students to login again. You will probably use this button more than once in a class whereas Setup is something you are likely to use only once (assuming you don't switch activities).

Projection Needs

In addition to a TI-Navigator system, to make what's happening in the NetLogo program visible you will need a computer projection system for your "up-front" computer. For many of the activities, it is also helpful if the teacher can project what is happening on the calculator. To do this you'll need a teacher calculator (that comes with a video-out port on the back), an overhead projector, and a ViewScreenTM that attaches to the teacher calculator OR a teacher calculator, a video out converter from TI (calculator to RCA), and a place on the computer projection system for a second input. The latter option uses less projection space but will require you to switch between displays, while the first option takes more projection space but also allows you to see both NetLogo and the projected calculator display at the same time.

Selecting an Activity and Clearing the Server

The TISchool website acts as an interface to the server (think of it as a box that can store, receive and send out - "serve"- information for the activity). The server has to be told which activity you want to run in order to know what programs to send out to the calculators (and what information to get back from the calculators). When you first open a HubNet model in NetLogo, a dialog will mention "enabling" an activity. Often you'll first have to disable a previous activity before enabling the new activity. If not, skip the following directions for de- selecting and go straight to how to select an activity.

De-Selecting an Old Activity

To de-select an activity you'll need to log on to the server with your account number and password. You'll get a screen like the following. To de-select an activity click on the "Activity Name"

http://192.168.110.2/TISchoolNetHTML/index.html

Back Forward Stop Refresh Home AutoFill Print Mail

Address: http://192.168.110.2/TISchoolNetHTML/index.html

Live Home Page Apple Apple Support Apple Store iTools Mac OS X Microsoft MacTools Office for Macintosh MSN

Texas Instruments E&P Solutions

Classroom Network

Teacher N.W.U.'s Home Page

My Home
Log Out

Manage
Activities
Students
Sections
Curriculum
Teachers
Schools

Author
Activities
Components
Courses

Discussions
Help
Support

Your Enabled Activities

Sort by: Activity Name

#	Activity Name	Section Name	Course Name
1	AAA - Function Activity 2.8	N.W.U.	test

Your Sections

#	Course	Section
1	test	N.W.U.

© 1999, 2000, 2001 Texas Instruments. All rights reserved.

Internet zone

and you should then see a screen like the following.

http://192.168.110.2/TISchoolNetHTML/index.html

Back Forward Stop Refresh Home AutoFill Print Mail

Address: http://192.168.110.2/TISchoolNetHTML/index.html

Live Home Page Apple Apple Support Apple Store iTools Mac OS X Microsoft MacTools Office for Macintosh MSN

Texas Instruments E&P Solutions

Classroom Network

Activity Home

My Home
Log Out

Manage
Activities
Students
Sections
Curriculum
Teachers
Schools

Author
Activities
Components
Courses

Discussions
Help
Support

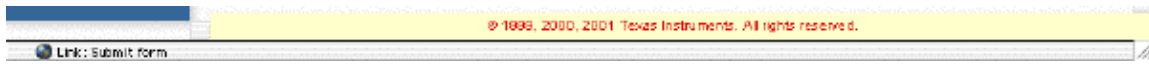
Activity Details

Activity P/N:	01-02-200-005745-001
Activity Name:	AAA - Function Activity 2.8
Section ID:	186
Section Name:	N.W.U.
Status:	Enabled for Class

Click on this image to disable this activity.
 Click on this image to enable this activity for TEACHERS ONLY.
 Click on this image to open the teacher console for this activity.

© 1999, 2000, 2001 Texas Instruments. All rights reserved.

Link: Submit form



Click on the "X" in the red circle (as shown). Voila, the old activity is now de-selected or disabled.

Selecting a New Activity

To select a new activity, return to the "My Home" screen and click on as shown.

A screenshot of a web browser displaying the "Classroom Network" interface. The browser's address bar shows "http://192.168.110.2/TISchoolNetHTML/index.html". The page has a yellow header with "Classroom Network" and "Teacher N.W.U's Home Page". On the left is a blue sidebar with navigation links: "My Home", "Log Out", "Manage" (Activities, Students, Sections, Curriculum, Teachers, Schools), "Author" (Activities, Components, Courses), and "Discussions" (Help, Support). The main content area has a "Your Enabled Activities" section with a "Sort by: Activity Name" dropdown and a table with columns "#", "Activity Name", "Section Name", and "Course Name". Below this is a "Your Sections" section with a table with columns "#", "Course", and "Section", containing one row: "1", "test", "N.W.U.". A green arrow points to the "N.W.U." text in the "Section" column. At the bottom of the browser window, there is a copyright notice: "© 1999, 2000, 2001 Texas Instruments. All rights reserved."

This will bring up a screen with all the activities available to your class. Click on the activity you want to enable (as shown below).

The screenshot shows a web browser window with the address `http://192.168.110.2/TISchoolNetHTML/index.html`. The page title is "Classroom Network" and the sub-header is "Section Home". The left sidebar contains navigation links for "My Home", "Log Out", "Manage" (Activities, Students, Sections, Curriculum, Teachers, Schools), "Author" (Activities, Components, Courses), "Discussions", "Help", and "Support".

The main content area displays "Section Details" in a yellow box:

- Section ID: 186
- Section Name: E. V. U.
- Course P/N: 01-01-200-005647-001
- Course Version: 001.001.001
- Course Name: test

Below this is a "Link Activity" button and a "Linked Activities" table:


#	Name	Status	
1	AAA - Disease 2.0	Disabled	<input type="button" value="Unlink"/>
2	AAA - Disease 2.1	Disabled	<input type="button" value="Unlink"/>
3	AAA - Disease 2.2	Disabled	<input type="button" value="Unlink"/>
4	AAA - Disease 2.3	Disabled	<input type="button" value="Unlink"/>
5	AAA - Elevators	Disabled	<input type="button" value="Unlink"/>
6	AAA - Function Activity 2.2	Disabled	<input type="button" value="Unlink"/>

At the bottom, there is a copyright notice: © 1999, 2000, 2001 Texas Instruments. All rights reserved.



You should now see this screen (or if you are returned to the home screen, click on the activity name). Click on the green circular icon (shown below).

The screenshot shows the same web browser window, but the page title is "Classroom Network" and the sub-header is "Activity Home". The left sidebar is identical to the previous screenshot.

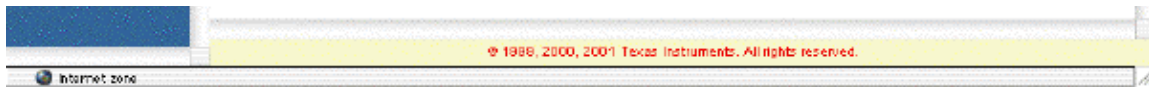
The main content area displays "Activity Details" in a yellow box:

- Activity P/N: 01-02-200-005761-001
- Activity Name: AAA - Disease 2.3
- Section ID: 186
- Section Name: E. V. U.
- Status:  Disabled

Below this are two instructions:

-  Click on this image to enable this activity for TEACHERS ONLY.
-  Click on this image to enable this activity for ALL.

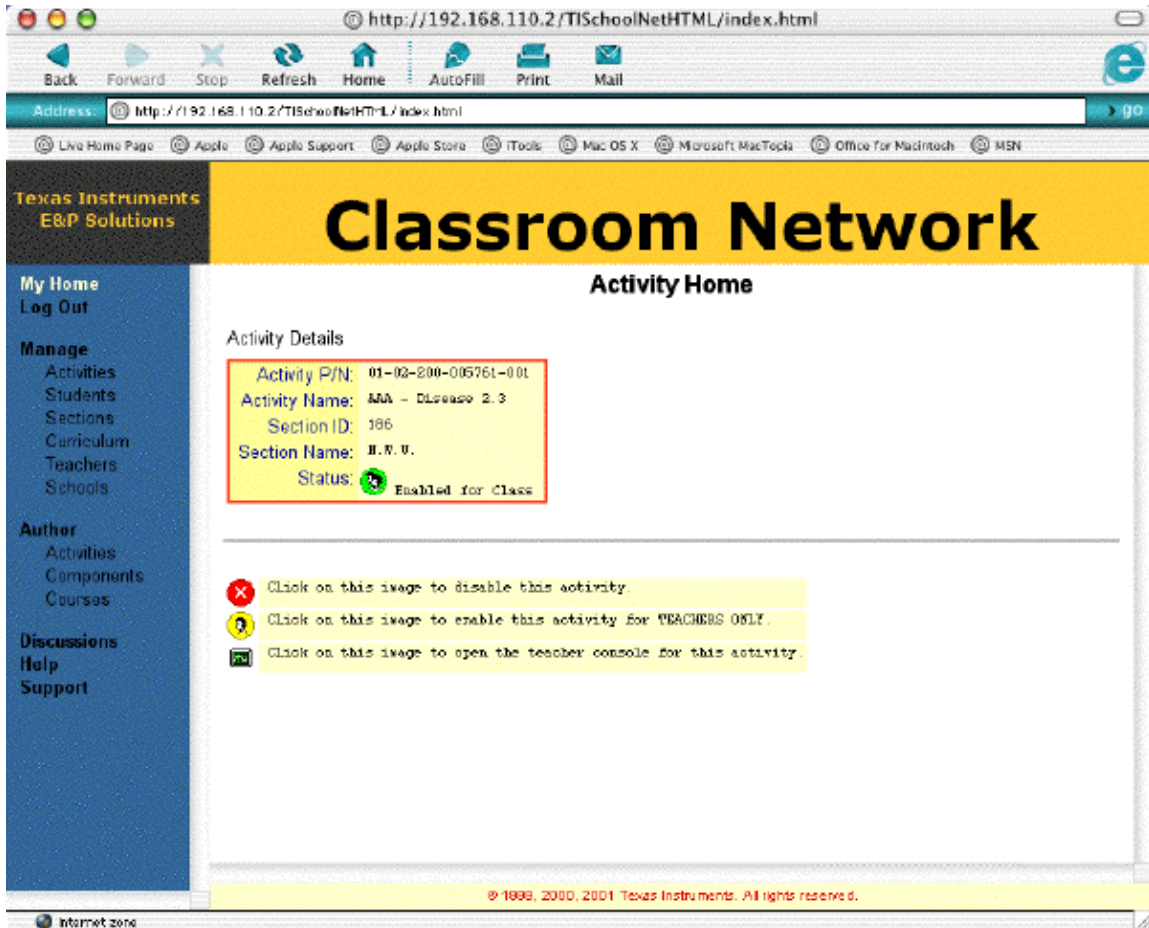
At the bottom, there is a copyright notice: © 1999, 2000, 2001 Texas Instruments. All rights reserved.



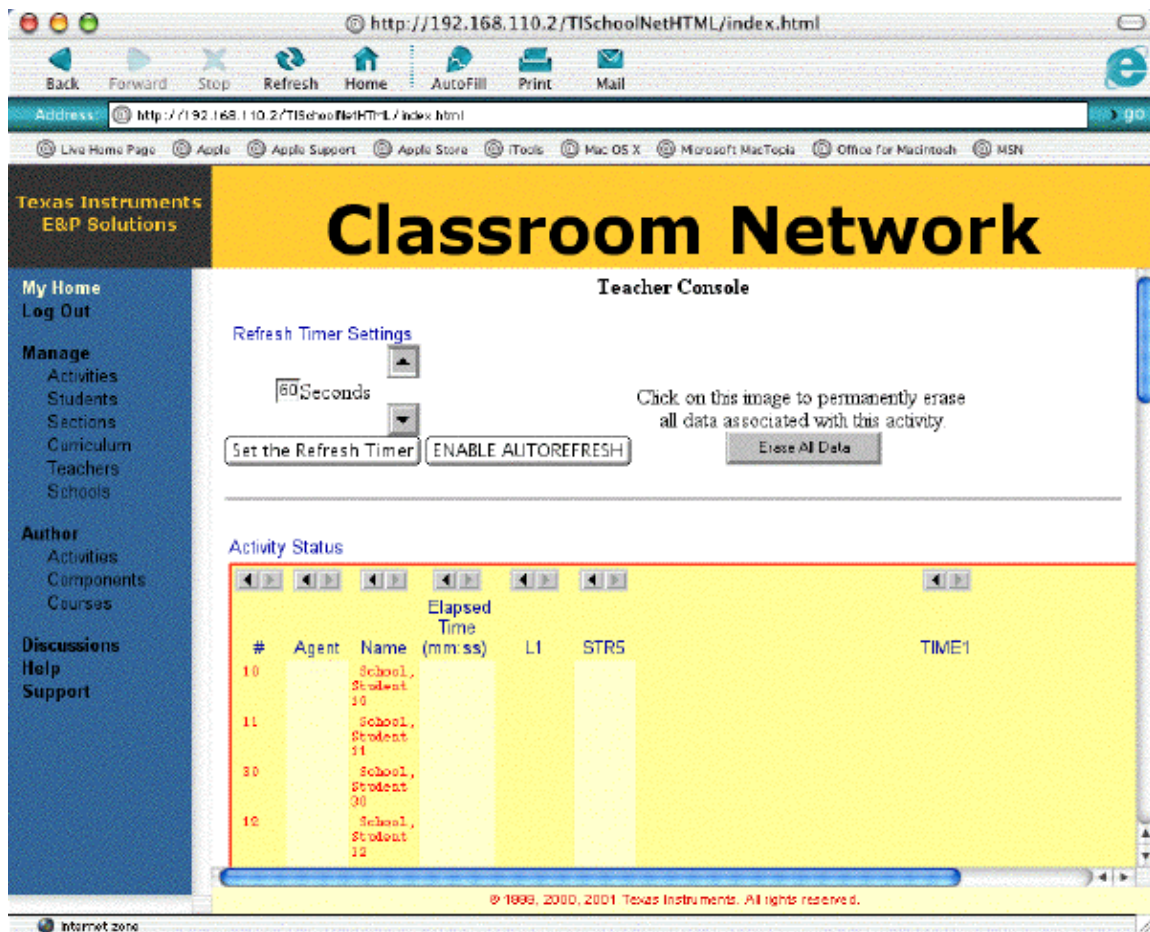
You will next need to clear the server of any old data that may be there from previous use of this activity. (Because you are already on the Activity Home screen you can skip the first step in the next section).

Clearing the Server

On the My Home screen click on the activity name. You should see the following. Now click on the green icon near the bottom of the screen (shown below).



This brings you to the screen that allows you to "Erase all Data" or clear the server. Click on the "Erase All Data" button.



Note that this screen keeps track of who's logged in and what data has been passed. This is the information that NetLogo uses for the participatory simulations.

Before each new group of students or before running a new activity, remember to clear the server. You are reminded to do this when you first open a HubNet activity or when you press the Setup button.

Erasing the Calculator Memory

Just as you have to clear the server, it is also a good idea to have the students completely clear the calculator's memory before logging on. You need to "reset" the calculator's memory. To do this, press to following keys in response to the calculator's prompts:

```
2nd
+ (to get "MEM")
7
1
2 (and you should now see "RAM Cleared").
```

Login with the Calculators

Once the calculators are hooked up to the NavigatorTM network by being plugged into a four- calculator "hub", press the blue APPS button on the calculator. Use the arrow keys to get to the menu option that says NETWORK. Press ENTER and you should see some letters appear in the lower right corner of the screen that tell you the calculator is accessing the network. Then a login screen should appear. Type in your login name (or number) and then your password.

Changing the Size of the Graphics Window

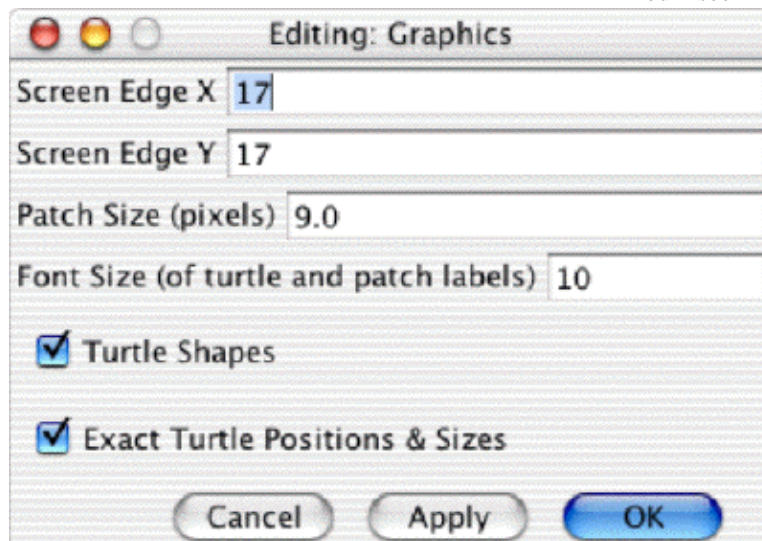
Some of the activities require you to be able to change the size of the NetLogo Graphics Window (the place where the turtles move around). This might happen because you want to change the dimensions of the space or because you want to make more (or less)

room for the number of students you have.

Press the More... button.



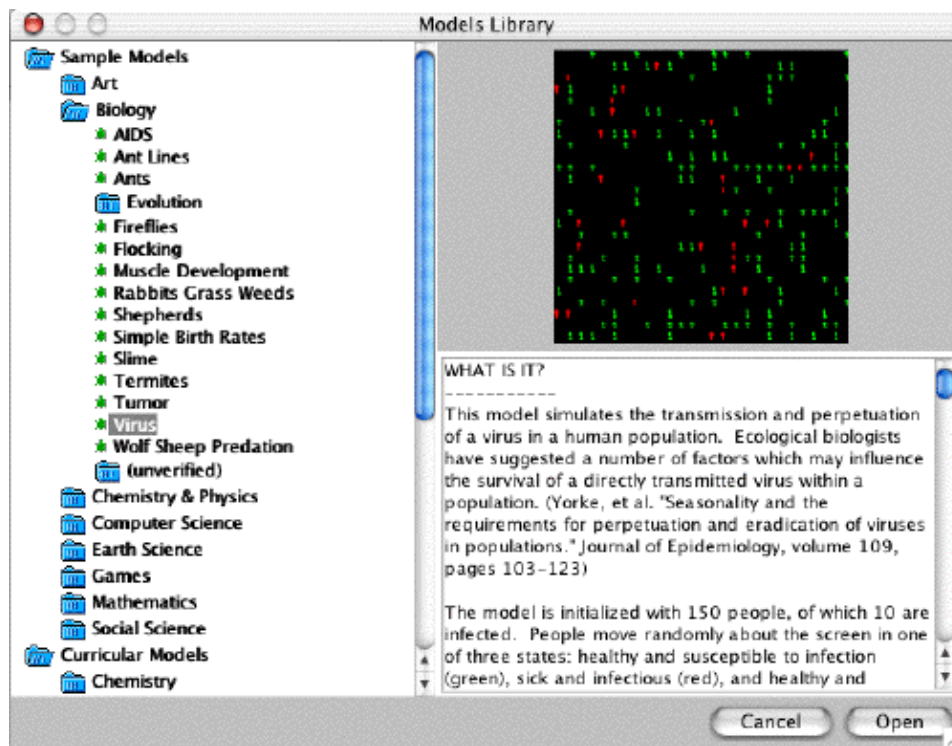
You'll see



Now change the values to what you need. Patch size is the size of the stationary grid squares (see the squares of "grass" in the sheep and wolves image shown earlier). The NetLogo Graphics Window is set up to be symmetric about the origin (0, 0) so "Screen Edge X" being 17 means the screen goes from $X = -17$ to $X = 17$.

Related Stand-Alone Models

The focus of these materials is on using the HubNet system to support participatory simulations. You are encouraged, however, to either write or modify models yourself or use the existing NetLogo models. Many models with topics ranging from viruses to ideal gases can be found in the models library (reachable through the NetLogo file menu).



These models are an important complement to and extension of the use of participatory simulations. For example, the Virus model shown above can naturally extend the ideas developed in relation to the Disease participatory simulation activity.

To Play or Not to Play

To get students started or to facilitate discussion you'll want to use a teacher calculator so the whole class can see what is going on. But then if you have to "play" the whole time, it will be hard for you to wander around your classroom and provide the support you'd like as well as keep track of the top-level story. What you may want to do is have a student near the front use the teacher calculator and keep it connected to the ViewScreen. Turn the ViewScreen off when the student is using the calculator, but when you want to use the calculator to talk to the class you can borrow it from the student and turn the ViewScreen on.

Careful of ON

Although this can be useful at times, pressing a calculator's ON button while it is logged in to the network will "crash" the calculator out of the network. Menus will appear allowing you to "Get the Activity" again if this happens by accident. You can immediately leave a simulation by pressing the ON, but generally you should use the "quit" commands in the calculator software since occasionally using ON as a shortcut will cause some memory management issues. These issues are really no big deal since you can always clear the memory (by pressing 2nd + 7 1 2) or, if it really gets stuck, pull the batteries out of the back and put them back in again.

Disease

Subject Areas

Mathematics, Science, Health, and Social Sciences

Topics

Disease Propagation

Abstract/Summary

In these two activities, students are members of a population in which a disease is spreading. The goal is to understand how the logistics curve emerges in relation to the dynamics of the spread of a simulated disease.

In a non-network based simulation, students literally walk around shaking hands and using dice to determine whether they have "risky" interactions. They then manually build graphs showing the number of students who get infected in each time period and use these to build graphs showing the total number sick at a time. This introduction prepares them to dive into the real-time HubNet simulation.

As the students participate in the real-time simulation, NetLogo creates a graph showing the number of people sick at each tick of the simulation's clock. This activity serves as a springboard to discussing modeling the spread of disease and to constructing models in general. Drawing from your students' experiences with the non-networked simulation, encourage them to think about how the simulation works and what strategies they might use to avoid catching the disease. The students and you can change attributes of the simulation (e.g., the sliders percent infection and/or initial number sick, step size, amount of space to move in, add in androids [that might be thought of as being like mosquitoes carrying a disease], and so on), try to predict what effects these changes will have and then see how well these predictions fit with what actually happens.

Prerequisites

Addition, Some graph interpretation.

Teacher Notes/Procedures

This unit is well suited to many different grade levels and classes from early middle school or late elementary to pre-calculus classes. As is true for all the participatory simulations, the activity itself can be extended well beyond the design of this unit. This is particularly true for science classrooms interested in using models to talk about logistic curves and natural processes as they can be modeled with the language of math and with computers. Additionally, it easily can be used in an elementary school classroom, as it does not mandate any complex prerequisite concepts. This particular application of this activity spans several different important concepts in both math and science, and can be adapted to a classroom interested in anything from graph interpretation, to health and even to very specific aspects of the logistics curve.

Activity I: Dice and Disease²

To begin, it is suggested that you use a non-Network simulation of a similar activity so as to give the students a better sense of the phenomenon they are about to simulate. In particular, the idea of there being a probability of getting sick is well supported by students using dice. In both this activity and in the networked version that follows there is no recovery, so if you get sick, you stay sick.

The non-HubNet simulation runs as follows. There are five time periods of a fixed duration, usually about a minute each. All the students are assigned an ID number, and walk around the classroom, each with a die, interacting with different students as they wander. Each "interaction" has both students roll his/her die. Each of them then records on the data worksheet (included in the Handouts section) the ID number of the person that they interacted with and the sum of their dice values.

After all five time periods, the class gathers, and the teacher reveals the dice total that is characteristic of a "risky interaction" (e.g., shaking hands after a sneeze, if this is modeling a cold). The teacher announces this number: "Those students with a combined dice roll of 5 or less become infected." This assigns a certain "chance" or probability that an interaction will result in infection. Now that this value has been announced, the students circle all of their risky interactions on their data sheets. The teacher then reveals what student (or students if you want) originally had the disease (for social reasons, it is often a very good idea to select this ID number at random [e.g., roll dice]). The selected student with the chosen number is who is sick at time = 0. This person can then infect other students during the first time interval.

The students then look on their sheets. If they interacted with this person during the first time interval they are now infected. This means that anyone that interacts with them during the second interval will get sick. This pattern continues where newly infected students can get other students sick during the next time interval. Discuss each interval one at a time and make sure you write down all the newly sick people during that interval on the data sheet. On the overhead or on the board, complete the data tables ("ID numbers of newly infected" etc.) as you go. This process continues until all five time-steps are carefully reviewed. Students will use

these results to plot graphs.

Next, students should graph their results. They can then discuss what the graphs they are looking at represent. To help with this discussion ask the students how the graphs would change, or remain the same, if the disease was more contagious (i.e., if you made the cut-off number greater than 5). Capture as many of these conjectures as you can. Encourage students not to be wishy-washy and then ask for students to commit to whether they agree with a given idea or not. Students can become very animated about their ideas. If everyone seems to be agreeing "too much" then push by asking whether it will be "exactly like this [whatever this is]" or whether it might be a little different? How so?

What is powerful about the HubNet version of this activity is that the class can explore these possibilities and do so in a way that allows them to readily compare various trials or "runs" of the simulation (the calculator can receive and display up to three different data sets for comparison). There are many aspects of disease spread that can be explored in this way.

Activity II: HubNet Disease Simulation

This activity requires a complete TI-Navigator system and the HubNet model named "Disease" found in the NetLogo Models Library.

When you open the HubNet model in NetLogo the software will ask you to login with your ID and password. This connects you to the activity server so NetLogo can interact with the data moving from and to the calculators. You will be told to enable a particular activity and clear the server of any leftover data. How to do this is discussed in the "Top Level Tips" at the beginning of this booklet. Follow the QuickStart directions at the top of the NetLogo screen to run the activity.

You will get to a place where the QuickStart Instructions tell you to have the students login. Have them login. They will see a screen that tells them they are doing the Disease simulation and after pressing ENTER they will get a menu with the following options:

- Simulation
- View Data
- Reset
- Use Calc
- Quit

The "-" tells you what option you are about to select. Up and down arrows allow you to move between these. Press ENTER with Simulation selected and students will see a screen similar to this:

```

2 IS A          :
GREEN
WOLF
TURTLE

PRESS ENTER

```

The students should remember their "turtle" shape and color so that they can find it on the projected NetLogo screen. When they press ENTER they will see a screen showing just their individual locations on a Cartesian coordinate system.

```

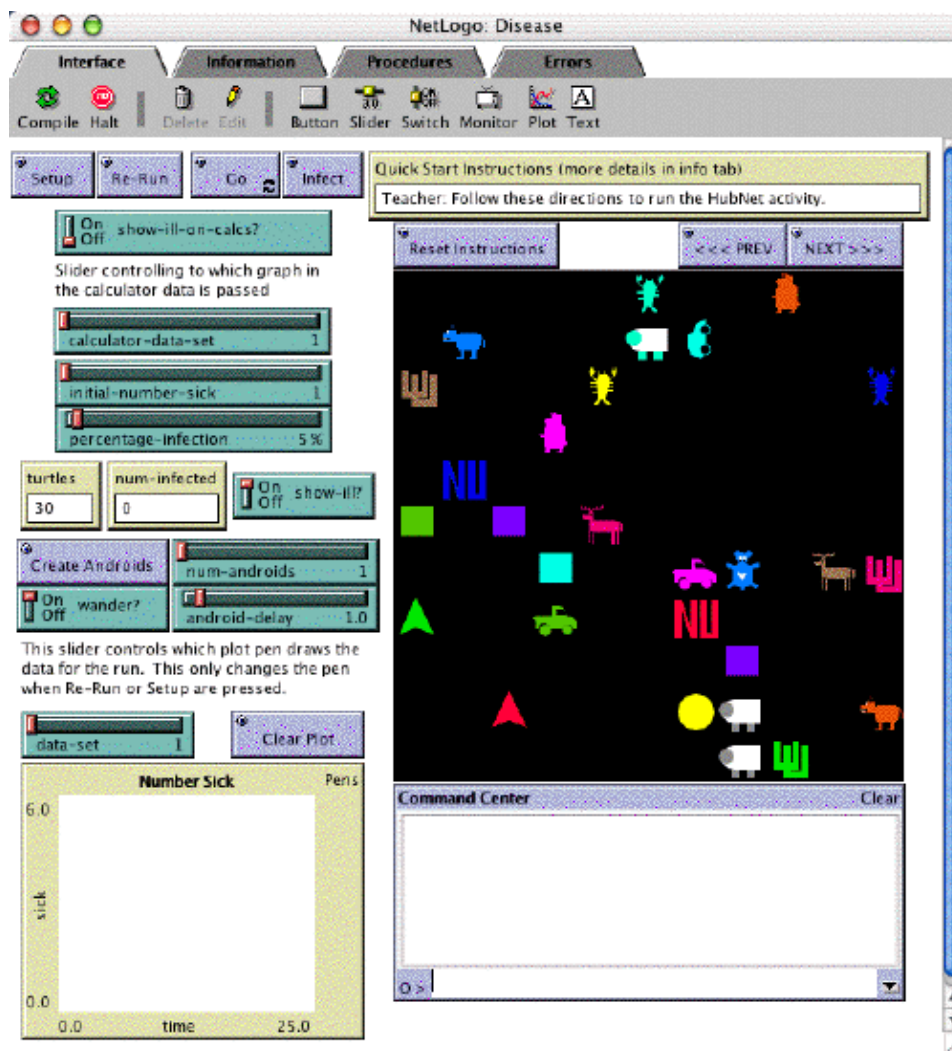
X=1 Y=-5 STEP=1
|-----|
|               |
|               |
|               |
|               |
|               |
|               |
|               |
|               |
|               |
|-----|
| BACK | | | STEP |

```

Students can use the arrow keys to navigate around the screen. On the up-front display, they should be able to find their own shapes

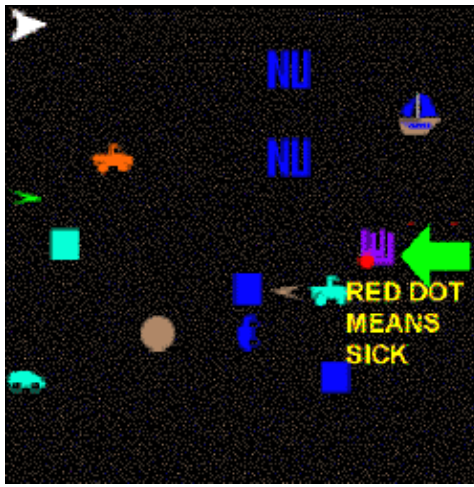
as well as see the shapes of their fellow students. Initially they move by one step when they press an arrow key. They can modify the size of their step by pushing the "STEP" softkey, and change it to a value between 1 and 5.

Let the students identify themselves on the screen by scrolling around with the arrow keys on their calculators.



At the top of their calculator screens students can read off the x and y coordinates of their positions. As a quick check of how everything is working, including students' ability to find a move their icons, we often have them move their points until the y value equals the x value. You should see a line form on the screen as the students move their turtles (and this hints at the kinds of things we do in Function Activity). If you have the students do this quick check, be sure to have them move apart before you get someone sick (it's not a good idea to start off near or even "on top" of people if someone is about to catch a cold).

Once they have become comfortable with the interface, make someone sick by clicking on the "INFECT" button on the NetLogo interface. The initial-number-sick slider is set to "1" so one person will get sick. In the beginning, leave the "show-ill?" switch on, so the students can see who is infected. To show who is sick, a red ball becomes part of the icon.



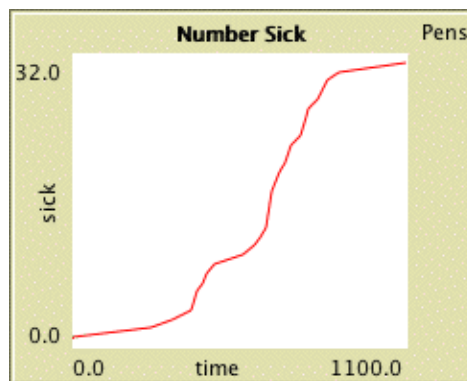
The calculator can also let students know that they are sick. Students can try to maintain their health as long as they can. As the activity continues draw attention to the "Number Sick" graph (shown below) especially as new students get sick.

Note that every time we have run this activity, including with all sorts of adults, the sick people end up chasing the well people. So if you have middle schoolers and they do this, be assured this is not an age-specific trait (and it does lead to an animated engagement with the activity).

Getting Simulation Data into the Calculators and Discussion

For any of the sequence of simulations, it is possible to send the data out to the calculators for students to analyze on their own or in small groups. It is even possible to send data from up to three separate trials back to the calculators for the purposes of comparison. How this works is NetLogo can send the data to three distinct lists using the list selection slider in the interface. To get data into the calculators, the students should get to the Menu screen and then select the "View Data" option. If there is any data available, it will now be displayed as a statplot. If multiple sets of data are available, then the names of the available trials will appear in softkeys at the bottom of the calculator's display screen. Press an available softkey to toggle on or off the display of a statplot for a data set. This feature allows the results from multiple plots to be examined individually or, for the purposes of comparison, together on the same plot. Pressing the right or left arrow keys puts the calculator in "trace" mode allowing you to move between points in a data set. Up and down arrow keys allow you to move between datasets. Pressing Enter returns you to the screen with the softkey menu (from trace mode). Note too that you can quit the activity and use the function graphing or regression capabilities of the calculator. So, for example, if you like, you can use the calculator's built-in logistics regression for analyzing the respective data sets. We suggest that you wait a while before jumping to this. A key aspect of the HubNet design is for each student to have powerful tools of analysis in their own hands and to become increasingly capable in the use of these tools in relation to analyzing meaningful data sets they were part of creating and/or are invested in.

For discussion ask the students, what is this graph measuring?



When are people getting sick the fastest (often students will struggle with whether it is when the graph is highest or "steepest")? When is the disease slowing down its spread and why? When is it speeding up or spreading faster and faster? When are the most people sick? Try and draw attention to the shape of the graph and the overall story it seems to tell (without necessarily saying anything, one way or another, about the "logistics curve"). Also have students articulate their strategies for staying well (e.g., you

might see some students along the edges, moving with large steps).

Then the question can become how might the graph (or values) be different if the activity was run again with some key parameter changed? We are about to run it again with the students not being able to see who is sick. But you can also explore what would happen if the percent infection was higher, or there were more (or fewer) people in the class, or if there were more people sick at the beginning, or if everyone only took big steps or small steps, or even introduce androids (which might be thought of as something like mosquitoes carrying a disease) and ask how that might change things. You can then re-run with the parameters changed and see how the students' predictions bear out. We have even found it can be worthwhile running the simulation several times with nothing changed to see which patterns "stay the same." This can also be done more quickly later with just androids, as sometimes students may not be as engaged by running an activity again the same way (note that "in reality," for reasons having both to do with chance and with the student strategies evolving, the graphs for identical settings can be quite different ... but almost always with the same overall shape ... hmmm ... maybe there is something really powerful and general about this logistics curve business after all ...). Be open to following student-generated conjectures and possibilities.

Re-Running the Activity

Now set the Show-III? switch to "off." Move the calculator-data-set slider to "2" so that both the previous data and the data you are about to collect will be available on the calculators (if you forget to move the slider, the new data set will overwrite the old set). Have all the students exit to the calculator Main Menu. Press the Re-Run button and follow whatever directions might appear. It is important that all the students are in the calculator Main Menu before pressing the Re-Run button since otherwise the students will not get the new settings sent by NetLogo. Before rerunning the simulation, push the students to articulate what might be different this time and why. Questions like "Will it happen faster or slower?", "Will everyone still get sick?", "Will the graph be stretched or shrunk, or will it be a different shape?", "How might your strategies have to change?" should get a heated exchange going. Again, if you need to get students more into committing to different possible stances, you can ask whether things will be "exactly the same". Remember to ask WHY they think things will be different. As they run through the simulation, they will start to hypothesize as to who is infected and who is not. Now have the students choose the Simulation option from the calculator Main Menu.

Once the simulation is completed discuss the results, especially in relation to the conjectures students presented earlier. Also explore their strategies for avoiding getting sick, and how they might go about figuring out who it was that was sick at the beginning. Discuss how this might be done for a "real" disease.

In comparing runs, ask students whether, with real diseases, you can always see who is sick. Are there diseases where someone might be sick and not know themselves? You could even discuss the different ways diseases might manifest themselves (e.g., incubation periods, carriers, etc.). Another discussion might be about what makes a really "bad" disease versus a less bad disease. Obviously, a disease being fatal is really "bad" but there is much, much more to it than that. See if you can push students to talk about what kind of role these other factors could have. You might get to this point by asking, "So what would happen in our simulation if the second you got a disease you died, would everyone be likely to catch this kind of disease?" A small modification to the code would allow you to explore this possibility and related ones (allowing people to transmit the disease for some number of "ticks" of the simulation clock before expiring).

Using/Extending/Authoring NetLogo Models and Activities

Following up on the idea of possibly changing the way a simulation works, a key feature of the NetLogo environment (unlike "closed" simulations like SimCityTM) is that you have complete access to the code that makes the simulation or model work. This can allow you to actually see and better understand what's going on, change the code to explore new possibilities, or even get ideas for building new models or simulations. Clicking on the Procedures tab allows you do see the NetLogo code. You might want to look at some of the stand-alone models, as these will not have extra code for communicating with the network. The code is designed to be relatively easy to understand (drawing on the lessons learned from the Logo programming language) and is intended to capitalize directly on the students' first-person reasoning and experience. An introductory challenge can include having the students read through the code and try to come up with a flow chart of how the program behaves; this will familiarize them with both the code and the logic behind our models. As is true will all NetLogo models or simulations, start by looking for the "Go" procedure in the Procedures Tab as this reveals the "top level" story of the simulation. The code is extensively commented (comments are the programmer's notes to you about what the code is doing). And of course, we very much encourage you to reach in and change the code to explore how it works or build new possibilities. Further information on NetLogo is available at <http://ccl.northwestern.edu/netlogo/>.

Time Considerations

At least 3 days for the main unit; additional time may be required for NetLogo extensions.

Curriculum Standards

According to the National Council of Teachers of Mathematics, students should learn to:

- Create and use representations to organize, record and communicate mathematical ideas
- Select, apply and translate among mathematical representations to solve problems
- Use representations to model and interpret physical, social and mathematical phenomena
- Use mathematical models to represent and understand quantitative relationships
- Analyze change in various contexts
- Organize and consolidate their mathematical thinking through communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
- Make decisions about units and scales
- Analyze and evaluate the mathematical thinking and strategies of others
- Make and investigate mathematical conjectures
- Develop and evaluate mathematical arguments and proofs
- Use the language of mathematics to express mathematical ideas precisely
- Identify trends of bivariate data, and find functions that transform the data so that it can be modeled.
- Understand and apply basic concepts of probability
- Describe events as likely or unlikely
- Discuss the degree of likelihood using words such as certain, equally likely and impossible
- Understand that the measure of the likelihood of an event can be described by a number between zero and one
- Apply appropriate techniques, tools and formulas to determine measurements.

Curriculum Objectives

- Through conversation and responses, students can describe the reasoning behind their predictions, and evaluate others strategies for meeting challenges.
- Through this activity, students can apply concepts of probability to a real-world situation.
- Students can analyze different representations of data and compare different forms of measurement.
- Through the activity, students can also begin to model and interpret physical phenomena in the language of mathematics.

Support Resources in NetLogo

These are resources that are included in the HubNet Disease model.

QuickStart Instructions

- Teacher: Follow these directions to run the HubNet activity.
- Optional: Zoom In (see Tools in the Menu Bar)
- Optional: Change any of the settings.... If you do change the settings, press the SETUP button.
- Press the GO button.
- Everyone: Reset the RAM on your calculator (2nd MEM 7 1 2).
- Login to your calculator.
- Choose SIMULATION at the calculator Main Menu.
- Remember your shape and color
- When you press enter again you will enter the simulation.
- Teacher: Have the students move their turtles around to... acquaint themselves with the interface.
- Press the INFECT NetLogo button to start the simulation.
- Everyone: After some time of infections, choose...
- VIEW DATA at the calculator Main Menu to receive the data.
- Teacher: To rerun the activity, do not clear the server.
- Stop the simulation by pressing the NetLogo GO button.
- Everyone: Exit to the calculator Main Menu.
- Teacher: Change any of the settings that you would like.
- To overlay plot data on the calculators... change the value of the slider CALCULATOR-DATA-SET.
- If you set CALCULATOR-DATA-SET to a value that already... had data in it, the new data will over-write the old data.

- Press the NetLogo RE-RUN button.
- Everyone: Choose SIMULATION at the calculator Main Menu.
- Teacher: Restart the simulation by pressing... the NetLogo GO button again.
- Infect some turtles and continue.
- Teacher: To start the simulation over with a new group,... stop the model by pressing the NetLogo GO button, if it is on.
- Have everyone, including yourself, logout of their calculators.
- Press the ERASE ALL DATA button on the TISCHOOL site.
- Press the NetLogo SETUP button.
- Follow these instructions from the beginning again.

Information Tab

WHAT IS IT?

This model simulates the spread of a disease through a population. This population can consist of either students, which are turtles controlled by individual students via the TI Navigator Network, or turtles that are generated and controlled by NetLogo, called androids, or both androids and students.

Turtles move around, possibly catching an infection. Healthy turtles on the same patch as sick turtles have a PERCENTAGE-INFECTIOIN chance of becoming ill. A plot shows the number of sick turtles at each time tick, and if SHOW-ILL? is on, sick turtles have a red circle attached to their shape.

Initially, all turtles are healthy. A number of turtles equal to INITIAL-NUMBER-SICK become ill when the INFECT button is depressed.

Whenever a new turtle becomes ill, data lists time-data and sick-data are sent to the TISchool server. These are then accessible via the VIEW DATA option on the calculator menus. The data is displayed in plots 1, 2, and 3, whose numbers correspond to the slider PLOT-NUMBER in the NetLogo model.

This activity requires the TI Navigator activity AAA - Disease 2.3

For further documentation, see the Participatory Simulations Guide found at <http://ccl.northwestern.edu/ps/>

HOW TO USE IT

IMPORTANT NOTE: Before running this with a class, be sure to press the ERASE ALL DATA button in the teacher console for the activity AAA - Disease 2.3 on the TISchool website. If you choose to exit the program and return (using the USE CALC option at the Main Menu) or choose the RESTART option, *DO NOT* clear the server.

QUICKSTART INSTRUCTIONS:

Contains instructions as to how to quickly setup the model, calculators, and TISchool web page so as to run this activity. The instructions can be found below:

Teacher: Open the TISchool site in your web browser.
 Enable activity AAA - Disease 2.3
 Open the teacher console and press the ERASE ALL DATA button.

If it is not open already, open the NetLogo model.
 If you are prompted by a Login dialog, enter your teacher id and password

and any other necessary information.

Optional- Zoom In (see Tools in the Menu Bar)

Optional- Change any of the settings. If you do change the settings, press the SETUP button.

Press the GO button.

Everyone: Reset the RAM on your calculator by pressing the following keys:

2nd MEM 7 1 2.

Login to your calculator.

Select the SIMULATION option from the calculator Main Menu.

The calculators will display the shape and color you will have in the NetLogo model. Remember these so that you can find your turtle. When you press enter again you will enter the simulation.

Teacher: Have the students move their turtles around to acquaint themselves with the interface.

When you are ready to simulate the spread of the disease, press the INFECT button in the NetLogo model.

Everyone: After some time of infections, choose VIEW DATA at the calculator Main Menu to receive the data that was collected by NetLogo.

Teacher: To rerun the activity, do not clear the server.

Stop the simulation by pressing the NetLogo GO button.

Everyone: Exit to the calculator Main Menu.

Teacher: Change any of the settings that you would like. Now might be a good time to change to which set of data NetLogo sends information. You do this by changing the value of the NetLogo CALCULATOR-DATA-SET slider. If you set CALCULATOR-DATA-SET to a value that already had data in it, the new data will over-write the old data.

Press the NetLogo RE-RUN button.

Everyone: Choose SIMULATION at the calculator Main Menu.

Teacher: Once everyone has chosen SIMULATION from the Main Menu.

Restart the simulation by pressing the NetLogo GO button again.

Infect some turtles and continue.

Teacher: To start the simulation over with a new group, stop the model by pressing the NetLogo GO button, if it is on.

Have everyone, including yourself, logout of their calculators.

Press the ERASE ALL DATA button on the TISCHOOL site.

Press the NetLogo SETUP button.

Follow these instructions from the beginning again.

BUTTONS:

SETUP - clears all turtles and patches and the plot. This should only be pressed when starting out with a new group of users since all data is lost.

GO - runs the simulation

RE-RUN - cures all turtles, clears the plot, and clears the lists sent to the calculators. This should be used to setup the model again for collecting more data or running the model again with the same users connected. Every user should be in the calculator Main Menu when this is pressed.

CREATE ANDROIDS - adds randomly moving turtles to the simulation

INFECT - infects some of the turtles in the simulation

CLEAR PLOT - clears the plot

NEXT >>> - shows the next quick start instruction

<<< PREVIOUS - shows the previous quick start instruction

RESET INSTRUCTIONS - shows the first quick start instruction

SLIDERS:

NUM-ANDROIDS - determines how many androids are created by the CREATE ANDROIDS button

ANDROID-DELAY - the delay time, in seconds, for android movement- the higher the number, the slower the androids move

INITIAL-NUMBER-SICK - the initial number of turtles to become infected when the INFECT button is pressed

PERCENTAGE-INFECTON - sets the percentage chance that every tenth of a second a healthy turtle will become sick if it is on the same patch as an infected turtle

CALCULATOR-DATA-SET - the number of the graph in the calculator to which the current data will be sent and display on the calculators when the VIEW DATA menu option is chosen

DATA-SET - determines the plot pen to draw the data with in the plot. This only changes the plot pen when RE-RUN or SETUP are pressed.

SWITCHES:

WANDER? - when on, the androids wander randomly. When off, they sit still

SHOW-ILL? - when on, sick turtles add to their original shape a red circle. When off, they can move through the populace unnoticed

SHOW-ILL-ON-CALCS? - when on, the calculators will show a label indicating if the turtle is sick or not. This only is sent to the calculators when the RE-RUN or SETUP buttons are pressed. The calculators receive this value when the SIMULATION option is chosen from the calculator Main Menu.

MONITORS:

TURTLES - the number of turtles in the simulation

NUM-INFECTED - the number of turtles that are infected

PLOTS:

NUMBER SICK - shows the number of sick turtles versus time

CALCULATOR INFORMATION

TEACHER CALCULATOR:

Students and teacher have identical calculator programs.

STUDENT CALCULATOR:

When the program runs, it checks the server for a "flag" to indicate whether the program is being restarted. If the flag isn't found, then a splash screen will display saying "DISEASE SIMULATION" and variables will be initialized. Then, the main menu will display.

At the main menu, you will find five options:

SIMULATION - join the simulation

VIEW DATA - view data from the simulation

RESTART - restart, clearing all data
 USE CALC - use the built in functionality of the calculator
 QUIT - quit, clearing all data from the calculator

CALCULATOR MENU OPTIONS:

SIMULATION:

When you choose to join the simulation, a message pops up letting you know what shape and color you will have in the NetLogo simulation. This shape and color is randomly determined each time you run the activity, and you might share a shape and color with somebody else. There are many possible shapes and colors for the turtles.

On the calculator a coordinate axis will appear, along with a small square representing the position of that student's turtle. A softkey menu will also appear, with two options: BACK and STEP

Arrow keys - move the turtle

BACK - returns to the MAIN MENU

STEP - brings up a menu, where you can choose between steps of 1 thru 5.

Pressing the ENTER key also allows you to change the step-size.

MATH - makes your turtle flash red for while- this can help you find your turtle

VIEW DATA:

When you choose this option, data from the simulation is downloaded. Up to three data sets can be collected and displayed as PLOT1, PLOT2, and PLOT3. Initially, the plots are shown together, and you can toggle plots on and off using the middle three softkeys. BACK returns to the MAIN MENU, and RFSH collects fresh data from the NetLogo model.

RESTART:

Restarts the activity without the need to rerun the programs.

USE CALC:

This allows you to temporarily leave the program, use the built in functionality of the calculator, and then return to the activity with your data preserved. When you leave the program, the data lists from NetLogo are automatically placed in the stat editor. To return to the program, run DISEASE on the calculator.

QUIT:

This quits the program, clearing all data and restoring your previous graphics settings.

THINGS TO NOTICE

No matter how you change the various parameters, the same basic plot shape emerges. After using the model once with the students, ask them how they think the plot will change if you alter a parameter. Altering the initial percentage sick and the percentage infection will have different effects on the plot.

THINGS TO TRY

Use the model with the entire class to serve as an introduction to the topic. Then have students use the NetLogo model individually, in a computer lab, to explore the effects of the various parameters. Discuss what they

find, observe, and can conclude from this model.

EXTENDING THE MODEL

Currently, the turtles remain sick once they're infected. How would the shape of the plot change if turtles eventually healed? If, after healing, they were immune to the disease, or could still spread the disease, how would the dynamics be altered?

CREDITS AND REFERENCES

This activity and associated models and materials was created as part of the project: PARTICIPATORY SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. The project gratefully acknowledges the support of the National Science Foundation (REPP program) -- grant number REC #9814682.

Copyright 1999 by Uri Wilensky & Walter Stroup. Updated 2001,2002. All rights reserved.

Permission to use, copy, or modify this software and its associated documentation, models and curricular materials for educational and research purposes only and without fee is hereby granted, provided that this copyright notice and the original authors' names appear on all copies and supporting documentation. For any other uses of this software, in original or modified form, including, but not limited to distribution in whole or in part, specific prior permission must be obtained from Uri Wilensky and Walter Stroup. These programs shall not be used, rewritten, or adapted as the basis of a commercial or hardware product without first obtaining appropriate licenses from Uri Wilensky & Walter Stroup. We make no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

To refer to this model in academic publications, please use: Wilensky, U. & Stroup, W. (1999). NetLogo HubNet Disease model. <http://ccl.northwestern.edu/netlogo/models/HubNetDisease>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

In other publications, please use: Copyright 1999 by Uri Wilensky and Walter Stroup. All rights reserved. See <http://ccl.northwestern.edu/netlogo/models/HubNetDisease> for terms of use.

Equipment/Materials Needed

- TI Navigator System
- NetLogo Software
- Dice (one for each student)
- Projection System
- Personal computer
- NetLogo model: Disease.nlogo
- Student worksheets

Keywords

- Probability
- Modeling
- Logistic Curve
- Exponential Growth
- Rate of Change
- Derivative

[Disease Handouts](#)

Function Activity

Subject Area

Mathematics, Science

Topics

Functions, Linear Equations, Graphing, Algebraic Equivalence

Abstract/Summary

Understanding what a function is and moving from a collection of points or a verbal description of a rule to an analytic expression are often very challenging tasks for students. This activity targets each of these learning issues and also can engage students with what it means for functions to be equivalent (e.g., $x + x$ being the "same" as $2x$). The function activity works by having students "become points" and move around in a Cartesian coordinate system according to rules like, "Move until your y-position is two times your x-position." As students move, NetLogo aggregates the points for the whole class and displays them. Then the points for the class are passed back to each of the students. The students can work on trying to develop analytic functions (e.g., $Y=2x$) that describe this rule and go "through" the points. The network can collect all the students' proposed analytic expressions and, if the class is encouraged to find "interesting" functions that go through these points (e.g., $y = 40x/20$), then there is a very easy transition into understanding what equivalence is about. In an Algebra class the ideas of equivalence - what for students starts off feeling like we're saying things are the "same" that really don't look alike - are typically associated with "rules for simplifying" and "factoring." Often these equivalence rules are approached in a way that doesn't allow students to see what a function is and what equivalence means (that you get the "same" picture on a graph or "same" x and y points on a table). Taking time with this activity addresses many of these challenging issues while also, at an even more introductory level, helping students get used to the convention of naming locations on the Cartesian plane. The activity should be repeated several times and can be returned to at different points in an academic year as you explore different kinds of functions. Science teachers [or, certainly, math teachers] can use this activity to help students understand how analytic expressions or mathematical "laws" can summarize patterns or relations observed in the world around us (e.g., $F = ma$ for a given mass with x standing for "a" and y standing for "F").

Note: if you are used to having students think of "x" as a (single) "hidden" number (what you "solve" for), this activity emphasizes the more general idea of x being a variable (i.e., capable of representing different values - like all the ones the students choose to embody in this activity) in a function that "connects" x's with y's. A function is a rule-machine or recipe you drop numbers into and get numbers out of. The variable idea of x (where x can become any value in the domain) is foundational for students' success in more graphically based approaches to algebra - what is often called "a function-based approach" to algebra - and to courses like Algebra II, Pre-Calculus, Calculus. (Solving then becomes a kind of comparison of distinct functions where "=" is one kind of comparison and is associated with where the functions "cross" or "touch". The solved-for x is the x-value where the functions touch. It is not the only value x can assume, just a special one in the comparison of two functions).

Prerequisites

Some introduction to basic number operations

Teacher Notes/Procedures

Introductory Activity or Display

Some teachers have used a preliminary activity where they set up a people-sized Cartesian coordinate system either in their classrooms or in some other (larger) space in the school (e.g., gym, cafeteria, main lobby) and have students move around according to rules similar to the ones they are going to use for the HubNet activity.

An alternative is to use QuickTimeTM movies of marching bands where sometimes it is hard to see what is going on and then, voila, a visible pattern emerges from each band member following his or her own "local" rule(s).

HubNet Function Activity

Getting Started

Like all the HubNet activities, begin by enabling the Function Activity on the server and then clear the server of any old data that may be on it (directions are in the Top-Level Tips section). You will be reminded to do this as you open the HubNet Function Activity model or press the Setup button. As you open the HubNet activity you will be asked to login.

Although the NetLogo program "presses" Setup for you automatically when you open it, you may want to get into the habit of pressing the Setup button each time you start a new activity or begin work with a new class. Remember, Setup will typically be pressed only once during a class period and requires students to login after it is pressed. If you want to do another round of an activity you typically don't want to go through the whole process of having students login again and so on. To do another round of an activity press the Re-Run button. Re-Run is typically used multiple times in a class period and does not require students to repeat the login sequence.

One of the things that NetLogo does for you is to send a collection of settings that determine features of the calculator graphics window (e.g., xmax, ymax, etc.). When you press Setup or Re-Run these settings are sent to the server where the calculators can get them. If you want to change these settings (either right from the start or after playing a round), change them, and then press the Re-Run button, to make sure these settings are sent to the server. Then follow the QuickStart Instructions associated with restarting the activity.

Login and Getting Oriented

With the NetLogo program now running we are ready for the students to login. Before doing this it is a good idea to have them clear the calculator memory. This is described in the Top-Level Tips section (2nd + 7 1 2). The login sequence is also described in the Top-Level Tips section (press APPS then NETWORK then login). You will also want to login alongside the students to be able to project, using a teacher calculator connected to a ViewScreenTM, what the students will see on their calculators. Having an upfront display will also be important later in the activity when the points are aggregated and the various student-generated functions are displayed.

When the students first login they will see a screen similar to this.

```

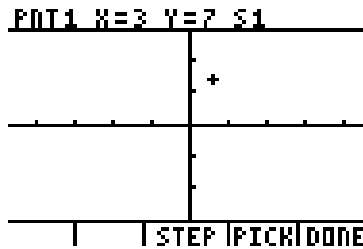
      _____
      FUNCTIONACTIVITY
      - PICKPNTS
      VIEWPNTS      RESTART
      CREATEEQN     USECALC
      VIEWEQNS      QUIT
      _____
                          SLCT
  
```

This is a home screen, called the calculator Main Menu that students can always return to at any point in an activity. Think of it as the lobby of a building. BACK or DONE softkeys will get you back to this lobby.

The "-" can be moved up and down using the arrow keys to select the different options. With PICKPNTS selected, either press ENTER or the SLCT softkey to go into where students can move their points around. Before jumping into the coordinate system, the students are told what the shape and color of their icons will be. They should remember these, as it will make "finding themselves" in the upfront space much easier.

Moving and Picking Points

When they press ENTER again they should see a screen with their point on it.



The students can move the given point around the space using the cursor (arrow) keys. Note how the x and y coordinates are displayed and updated at the top of the screen.

Students should move around and see if they can locate themselves in the upfront NetLogo screen (where everyone's point is projected).

The teacher should now give a verbal rule like, "Move until your y value is two times your x value." Help the student see what this would mean by pointing to the x and y coordinates displayed on the top of the screen and explaining that you want "this" y value to be two times the x value. Assuming it is not currently, tell them they have to move around until they find a spot where this is true (and that there are lots of them).

You can get some powerful feedback about student thinking as they start to move around. Typically, student movement will be concentrated in the first quadrant (and, closely related, at least some points will be in the second quadrant). As students are moving or after they've selected points you might ask them "Why do you think most of you are up here [pointing to the first quadrant]?" Either in this round or in a subsequent one encourage them to "spread out more" or be "more adventurous." Positive social pressures to be more creative or "out there" are a powerful and unique aspect of working in a network space. In the network space there is a "right level" of anonymity enabling students to take risks or even be "wrong" without having to be embarrassed by doing so. You are trying to use the students' association of "cool-ness" with "different-ness" toward the end of raising the level of the mathematical conversation. A similar dynamic should be encouraged later when students send in functions that go through these points. Yes, $Y=2x$ is perfectly correct but $Y=100x/50$ is more interesting.

Students can choose one or more points as they go by pressing the PICK softkey. Each point they choose will show up on their screen and be "stamped" on the upfront screen. Only the last point each student chooses will be the one sent to the whole class. Students can change the step size by pressing the STEP softkey and choosing one of the step size options.

Viewing Points from the Class

When they select DONE, the last point picked by each student is sent to the class and the students are returned to the calculator Main Menu. Move the "-" to VIEW PNTS and press ENTER or the SLCT softkey.

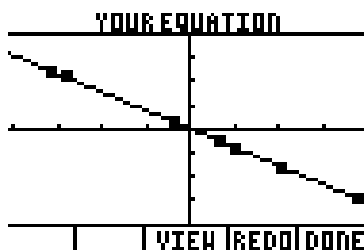
The last points picked by the entire class should now be visible on the students' calculator screens. A very powerful feature to use at this point is pressing the right and left arrows on the calculators to jump between the points. The x and y coordinates for each of the points become visible and you can ask, "Does this point satisfy the rule? Why or why not?" Pressing Enter will make the softkeys visible again. Press DONE or BACK to return to the main menu.

Picking an Equation

By selecting the CREATE EQN option in the main menu and pressing ENTER you can have the students create analytic functions that "go through" the points they sent in. Challenge your students to come up with functions that use division, or multiplication, etc. This is a place where this activity can take off as students submit functions and start comparing their functions with ones that other students submitted. You can encourage this process with questions like, "Can somebody come up with a function that uses division or multiplication? Powers? Etc."

At CREATE EQN, each student can enter a function and view it with the points before sending it to the class. This allows students to play in private first and then when they've found an interesting one, send it to the class.

NEW EQUATION
 $Y = -20X/40$



If their functions miss, they can press REDO to try again (without anyone else knowing that they may have missed). They can also press REDO if, after gaining some confidence, they want to enter a more interesting function.

NOTE: There is no "error trapping" in this program (unlike if you were using the Function capabilities of the calculator alone). Students must enter expressions that can be interpreted. The #1 most common error is confusing the role of the negative key with the minus key. Minus is an operation; negative is a property of a number and confusing the two will cause the program to "crash out." The student will then have to re-login after first clearing the memory of the calculator.

When the student selects DONE, his or her current function is sent to the class.

Viewing Equations from the Class

Returning to the main menu after pressing DONE, the students should now select VIEW EQNS. They should now see a selection of the functions sent by the class. Again the features of the calculator can be used to take a closer look at these functions. The up and down arrows allow you to "jump" between lines. Note that the function for each line now appears on the calculator screen. Just as you may have for individual points, you can ask if the current function will go through the points. You can jump to points by using the right and left arrows. And finally, to get a new set of functions press NEXT. To return to a previous group of functions press PREV.

Note, USE CALC allows you to quit the program and just use the calculator "off line." If you want to then get back into the program, press the PRGM key and run the FXNACT program.

Re-Running the Activity

This is an activity where you'll want to cycle through a range of kinds of verbal descriptions. To do so, have students return to the calculator Main Menu and select ReStart. In NetLogo, if you want to change the size of the Graphics Window, change it to whatever size you want and press the Re-Run button. See the Top Level tips for more information regarding resizing the NetLogo Graphics Window. Note that NetLogo requires you to choose screen-sizes that are symmetric around the x- and y-axis (that is, with the origin in the middle). When the students choose the PICK PNTS option from the calculator Main Menu, they will get the new settings.

Now you are set to re-run the activity. The following are a series of challenges that can be done. We encourage you to not get "hard" too quickly but also not be afraid to challenge students. A wide range of challenging topics including the standard transformations of functions, combining functions, creating functions of y instead of functions of x can be engaged in these challenges.

Important Introductory Challenges:

Move until:

- your y value is -2 times your x (watch out for negative versus minus calculator keys)
- your y value is your x value plus 2 (would it make a difference if it was 2 plus your x value?) (addition is ___? [commutative])
- your y value is two times the sum of your x value and -1 (note how all the standard verbalizations can be used) (would the sum of x and -1 quantity times 2 be different?) (if needed, have half the class do one rule and the other half do the other; then enter functions for each; etc.) (multiplication is ___? [commutative]) (can they simplify this expression, is it really the same?) [don't be surprised if students may not think so]
- your y is 1/4 you x value.

Mid-Level Challenges:

Move until:

- your y value is your x value times itself
- your x value plus your y value sums to 2 (this helps students understand the relationships between linear functions in standard form and slope-intercept form [which they'll have to use to "hit" the points])
- your x value is twice your y value (is this line both a function of x and a function of y?)
- your x value is your y value squared (is this line a function of both x and y?)

Tougher Challenges:

Move until:

- your y value is the absolute value [MATH key, right arrow, choose "abs"] of your x value. Do the full cycle. Not so hard. But ...
- your y value is the absolute value of your x value and now that you've found that take TWO steps up. (this begins an exploration of transformations)
- your y value is the absolute value of your x value, NOW take two steps down.
- your y value is the absolute value of your x value, NOW take two steps to the right. (this is typically very difficult for students [$\text{abs}(x-2)$])
- your y value is -2 times the absolute value of your x value, NOW take three steps to the right and four steps down (this takes students through a core chunk of the transformations in Algebra II or Pre-Calculus)
- Sequence:
 1. Move until your y value is 2 times your x value minus one Write down this point (x1, y1).
 2. Now, WITHOUT changing your x [no left or right arrow] Move until your y value is the negative of your X value plus 3. Write down this point (x2, y2).
 3. Now move until your y value is the sum of you Your y values from above (y1 plus y2).
 4. Now find a function that goes through this last Set of points (combining functions) ($[2x - 1] + [-x + 3]$ "really is" = $x + 2$!!)
- Sequence:
 1. Move until your y value is 3 times your x value plus 2 Write down this point (x1, y1).
 2. Move until your y equals your current x value (x1).
 3. Write down a rule that will take your y1 and turn It into x1.
 4. in CREATE EQN enter this rule in Y = form. Voila!, you have the inverse function.

We do NOT recommend completing all of these at once! A core subset of introductory ones, or ones of your own making can be done together. Then the Function Activity can be returned to at various points in a given few weeks or over a course of a year.

Time Considerations:

This activity should take one or two 60-minute class periods to complete and may be repeated as many times during a unit or academic year.

Curriculum Standards:

Grades 6 - 8:

Explore relationships between symbolic expressions and graphs of lines, paying particular attention to the meaning of intercept and slope; model and solve contextualized problems using various representations, such as graphs, tables, and equations; use graphs to analyze the nature of changes in quantities in linear relationships; relate and compare different forms of representation for a relationship; identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations; recognize and generate equivalent forms for simple algebraic expressions and solve linear equations.

Grades 9 - 12:

Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior;

approximate and interpret rates of change from graphical and numerical data; understand the meaning of equivalent forms of expressions, equations, inequalities, and relations; write equivalent forms of equations, inequalities, and systems of equations and solve them with fluency-mentally or with paper and pencil in simple cases and using technology in all cases; use symbolic algebra to represent and explain mathematical relationships.

Curriculum Objectives:

Students will develop the idea that functions are collections of points. Students will understand the concept of equivalent functions and demonstrate this understanding by producing several equivalent functions. This activity allows the teacher to get a snapshot of students' basic math skills (such as multiplication of negatives). Much more is also possible, see above.

Support Resources in NetLogo

These are resources that are included in the HubNet Function Activity program.

QuickStart Instructions

- Teacher: Follow these directions to setup the HubNet activity.
- Optional- Zoom In (see Tools in the Menu Bar) - optional
- Press the GO button.
- Everyone: Reset the RAM on your calculator (2nd MEM 7 1 2).
- Login to the calculator.
- Choose the PICK POINTS option.
- Remember your shape and color and press ENTER.
- Move around using the arrow keys to... acquaint yourselves with the interface.
- Teacher: Tell the students a verbal rule, such as... Move until your Y is twice your X.
- Optional- Press the NetLogo SET RULE button and enter... the verbal rule to be displayed in... the CURRENT VERBAL RULE monitor.
- Everyone: Pick some points that meet the requirements of... the verbal rule.
- This is done by moving to a point with the arrow keys and... then choosing that point by pressing ENTER or the PICK softkey.
- Press the REDO softkey to repick the last picked point.
- When you are done picking points, press the DONE softkey.
- Choose the VIEW POINTS option to view the last point chosen by... each member of the class as well as all the points chosen by you.
- When finished viewing the points, press the DONE softkey.
- Then, you can create an equation using the CREATE EQN option.
- Try to match the equation as closely as possible to... the last points picked.
- You may keep on trying different equations by pressing... the REDO softkey and entering a new equation at the prompt.
- When you have chosen the best-fit curve, press the DONE softkey.
- You can view the class' equations using the VIEW EQNS option.
- Press the RFSH softkey to get any new equations.
- When you are done viewing the equations chosen,... press the DONE softkey.
- Teacher: To rerun the activity, do not clear the server.
- Stop the simulation by pressing the NetLogo GO button.
- Press the NetLogo RE-RUN button.
- Press the GO button.
- Everyone: Exit to the calculator Main Menu.
- Choose the RESTART option from the calculator Main Menu.
- Choose the PICK POINTS option and continue.
- Teacher: To start the simulation over with a new group,... stop the model by pressing the NetLogo GO button, if it is on.
- Have everyone, including yourself, logout of their calculators.
- Press the ERASE ALL DATA button on the TISCHOOL site.
- Press the NetLogo SETUP button.
- Follow these instructions from the beginning again.

Information Tab

WHAT IS IT?

Students each find points that satisfy a spoken rule, such as "Move until your y value is twice your x value." The students can see, on their own calculators, their point and its x and y values, and on the NetLogo display they can see everyone's points moving in real-time.

Once everyone has picked one or more points that meet the rule, the students can view the last points picked by everyone. They also have the opportunity to attempt to create an equation that best fits the last point entered by everyone. Finally, they can view each other's equations.

This activity requires the TI Navigator activity AAA - Function Activity 2.4

For further documentation, see the Participatory Simulations Guide found at <http://ccl.northwestern.edu/ps/>

HOW TO USE IT

QUICKSTART INSTRUCTIONS:

Contains instructions as to how to quickly setup the model, calculators, and TISchool web page so as to run this activity. The instructions can be found below:

Teacher: Open the TISchool site in your web browser.
 Enable activity AAA - Function Activity 2.4
 Open the teacher console and press the ERASE ALL DATA button.

If it is not open already, open the NetLogo model.
 If you are prompted by a Login dialog, enter your teacher id and password and any other necessary information.
 Optional- Zoom In (see Tools in the Menu Bar)
 Press the GO button.

Everyone: Reset the RAM on the calculator by pressing the following keys:
 2nd MEM 7 1 2.
 Login to the calculator.
 Choose the PICK POINTS option.
 Remember your shape and color and press ENTER.
 Move around using the arrow keys to acquaint yourselves with the interface.

Teacher: Tell the students a verbal rule, such as "Move until your Y is twice your X."
 Optional- Press the NetLogo SET RULE button and enter the verbal rule to be displayed in the CURRENT VERBAL RULE monitor.

Everyone: Pick some points that meet the requirements of the verbal rule. This is done by moving to a point with the arrow keys and then choosing that point by pressing ENTER or the PICK softkey. Press the REDO softkey to repick the last picked point.
 When you are done picking points, press the DONE softkey.

Choose the VIEW POINTS option to view the last point chosen by each member of the class as well as all the points chosen by you.
 When finished viewing the points, press the DONE softkey.

Now that points are picked, you can create an equation of those points using

the CREATE EQN option. Try to match the equation as closely as possible to the last points picked. You may keep on trying different equations by pressing the REDO softkey and entering a new equation at the prompt. When you have chosen the best-fit curve, press the DONE softkey.

You can view the class's equations using the VIEW EQNS option. Press the RFSH softkey to get any new equations. When you are done viewing the equations chosen, press the DONE softkey.

Teacher: To rerun the activity, do not clear the server. Stop the simulation by pressing the NetLogo GO button. Press the NetLogo RE-RUN button. Press the GO button.
 Everyone: Exit to the calculator Main Menu. Choose the RESTART option from the calculator Main Menu. Choose the PICK POINTS option and continue.

Teacher: To start the simulation over with a new group, stop the model by pressing the NetLogo GO button, if it is on. Have everyone, including yourself, logout of their calculators. Press the ERASE ALL DATA button on the TISCHOOL site. Press the NetLogo SETUP button. Follow these instructions from the beginning again.

BUTTONS:

 SETUP - clears all turtles and patches. This should only be pressed when starting out with a new group of users since all data is lost.
 RE-RUN - sets up the model to be able to run again with the same users
 GO - runs the simulation
 SET RULE - displays an input dialog that allows the leader to enter the verbal rule. The entered rule is then displayed in the CURRENT VERBAL RULE monitor. This is meant for a convenience of the users and has no effect on the actual running of the simulation.
 NEXT >>> - shows the next quick start instruction
 <<< PREVIOUS - shows the previous quick start instruction
 RESET INSTRUCTIONS - shows the first quick start instruction

MONITORS:

 MOUSE X - shows the pxcor of the patch the mouse is currently on, or if the mouse is no longer over the graphics window, it displays the pxcor of the patch the mouse was last on
 MOUSE Y - shows the pycor of the patch the mouse is currently on, or if the mouse is no longer over the graphics window, it displays the pycor of the patch the mouse was last on
 NUMBER OF POINTS AT MOUSE - shows the number of turtles on the patch the mouse is currently on, or if the mouse is no longer over the graphics window, it displays the number of turtles on the patch the mouse was last on
 CURRENT VERBAL RULE - displays the last rule that was entered when the SET RULE button was pressed. This is meant for a convenience of the users and has no effect on the actual running of the simulation.

CALCULATOR INFORMATION

TEACHER CALCULATOR:

Students and teacher have identical calculator programs.

STUDENT CALCULATORS:

 To select points, choose option PICK POINTS from the calculator Main Menu.

Move the cursor with the arrow keys. To pick a point, press the ENTER key or PICK softkey. To remove the last picked point, press the REDO softkey. Be aware that the cursor will move back to the position of the point being removed. To change the distance that the cursor moves when you press an arrow key, press the STEP softkey. This allows you to choose a new distance by which to move the cursor.

When you are done picking points, press the DONE softkey.

You can choose the VIEW POINTS option to view the last point chosen by each member of the class as well as all the points chosen by you. When finished viewing the points, press the DONE softkey.

Then, you can create an equation using the CREATE EQN option. Try to match the equation as closely as possible to last points picked. You may keep on trying different equations, by pressing the REDO softkey and entering a new equation at the prompt. When you have chosen the best-fit curve, press the DONE softkey.

You can view the class's equations using the VIEW EQNS option. Press the RFSH softkey to get any new equations. When you are done viewing the equations chosen, press the DONE softkey.

THINGS TO NOTICE

 Notice how my-num and user-id are used in keeping track of a particular student's individual points.

THINGS TO TRY

 Here are a few verbal rules for the teacher to have the students make with their points:

Move until your y value is twice your x value.

Move until your y value is x times your x value.

Move until your y value is the inverse of your x value.

EXTENDING THE MODEL

CREDITS AND REFERENCES

 This activity and associated models and materials was created as part of the project: PARTICIPATORY SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. The project gratefully acknowledges the support of the National Science Foundation (REPP program) -- grant number REC #9814682.

Copyright 1999 by Uri Wilensky & Walter Stroup. Updated 2001,2002. All rights reserved.

Permission to use, copy, or modify this software and its associated documentation, models and curricular materials for educational and research purposes only and without fee is hereby granted, provided that this copyright notice and the original authors' names appear on all copies and supporting documentation. For any other uses of this software, in original or modified form, including, but not limited to distribution in whole or in part, specific prior permission must be obtained from Uri Wilensky and Walter Stroup. These programs shall not be used, rewritten, or adapted as the basis of a commercial or hardware product without first obtaining appropriate licenses from Uri Wilensky & Walter Stroup. We make no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

To refer to this model in academic publications, please use: Wilensky, U. & Stroup, W. (1999). NetLogo HubNet Function Activity model. <http://ccl.northwestern.edu/netlogo/models/HubNetFunctionActivity>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

In other publications, please use: Copyright 1999 by Uri Wilensky and Walter Stroup. All rights reserved. See <http://ccl.northwestern.edu/netlogo/models/HubNetFunctionActivity> for terms of use.

Equipment/Materials Needed:

- TI Navigator System
- NetLogo Software
- NetLogo model: Function Activity.nlogo
- Personal computer
- Projection System (for teacher calculator and computer)
- TI HubNet Activity: AAA - Function Activity 2.4

Keywords

- Plotting points
- Function
- Moving between verbal descriptions and formal expressions
- Equivalence
- Transformations

Gridlock

Subject Area

Mathematics, Science, Social Sciences

Topics

Emergence, Modeling, Optimization, and Measurement

Abstract/Summary

Students control traffic lights in a city. They can either manually switch their lights from red to green and back again, or set a phase for their light - set the time in the cycle when their light switches. The scenario used to introduce this activity to students is that with elections just a year away, the class has been commissioned by the Mayor of the City of Gridlock to help improve the traffic problem in her city. Goals for this activity include having the students develop strategies for improving traffic flow and, closely related, developing "metrics" or measurements for traffic so as to support their claims for having improved traffic. Part of establishing a metric depends upon deciding what aspects of the driving experience might matter the most to drivers (e.g., speed?, cars stopped?, wait time?), understanding how the metrics might be related or distinct (e.g., how is the number of cars stopped related to average speed?), creating metrics that may or may not be independent of the number of cars, and deciding which one or ones to include in a report to the mayor. This project engages many ideas related to how global patterns - for example, traffic flow - may be the result of lots of local interactions and strategies. From a curricular point of view, this activity has more of a problem solving or project-based structure to it than some of the other activities. Many specific content areas and mathematical ideas are engaged, but they are not organized in a traditional linear curricular sequence. Both problem solving and project-based approaches are strongly supported in national standards documents in both science and mathematics and in many state and local curricular guidelines. This activity also can be well integrated with social studies topics and raises many science, technology and society (STS) issues.

Prerequisites:

Arithmetic, Familiarity with traffic flow

Teacher Notes/Procedures:

This activity requires, in addition to a complete Navigator system and NetLogo software, NetLogo model Gridlock.nlogo and Navigator activity AAA - Gridlock 1.2.

The QuickStart directions take you carefully through each step that needs to be taken to run a round of the Gridlock activity, so rather than repeat these in detail we'll just focus on the top level "chunks" of this sequence and some of the learning and teaching possibilities that arise.

HubNet Login

Follow the Top-Level instructions printed at the beginning of this guide to enable the Gridlock activity, clear the server, and clear the student calculators. You will be prompted to enable the activity and clear the server when the HubNet Gridlock model is opened.

Setup the Grid

Unlike all the other activities where you need not plan ahead much for how many students log in (where, generally, the rule is the more the merrier), in this activity you need to have an intersection for each student to control. This means the traffic grid needs to have enough intersections and these need to be arranged in a two-dimensional, rectangular pattern. 30 students are easier to accommodate (e.g., using a 5 x 6 grid) than either 29 or 31. To accommodate these more difficult numbers you have some options (in descending order of what we've found to be preferable, but you should do what works best for you):

1. create more intersections than necessary and have some of them controlled by the computer (intersections which aren't controlled by students are automatically controlled by the computer, and you can selectively - one at a time - automate intersections that may have troubles during the simulation)
2. have a few students pair up
3. have some students control more than one intersection.

Once you've decided on the dimensions of the grid you'll use the sliders in the model to set these dimensions. Next you'll decide how many cars to include using a slider, and you'll have to decide if you want to run in manual or automatic mode. Manual mode allows students to change their lights when they want, automatic allows them to set at which time on a modular clock their light switches. We recommend starting with manual mode. After running the activity while only viewing the data from the Stopped Cars plot, we recommend turning on a different metric or even all three metrics (by setting display-which- metric to 4) for display in NetLogo. You can decide which of the three metrics to send back to the calculators. Unlike the Disease activity where each dataset is associated with different runs, in Gridlock the data for all three metrics is collected during a single run. This means that at the end of a particular run you can send this first metric, have the students get it, then switch the slider and, one at a time, send the other metrics to the calculators. The students can then get these new datasets. On the calculators each of these can be displayed one at a

time, all together, or in any pairings the students might want to look at. Note that the vertical scale is distinct from metric to metric and the scaling of the axes will be very different. This may mean that some datasets will be hardly visible if displayed at the same time as other datasets (metrics).

Now press Setup. Remember Setup is a "powerful" button, requires students to login, and is typically used only once in a class period. Re-Run is used to repeat the activity, doesn't require login, and may be used many times during a class period (assuming you keep the size of the grid the same).

Initial Student Login

After the setup you will be prompted to press the Initial Login button and then have students login. As they do, their user-ids will appear next to unique intersections in the simulated traffic grid. To control their intersection, students will have to choose between manual and automatic mode from the calculator Main Menu. Again, manual mode allows students to change their lights when they want, automatic allows them to set at which time on a modular clock their light switches. Start with manual mode.

Rather than tie up an intersection with a teacher calculator (thereby forcing you to switch between observer/facilitator and participant), a strategy we've used with almost all the activities and that is particularly effective for Gridlock is to have one of the students use the teacher calculator (you can use either your account or, preferably, the student's). To make some of the logistics easier, you can have the teacher calculator be on its own hub. Then you can demonstrate what to do when needed, but otherwise let the students be in charge of the system.

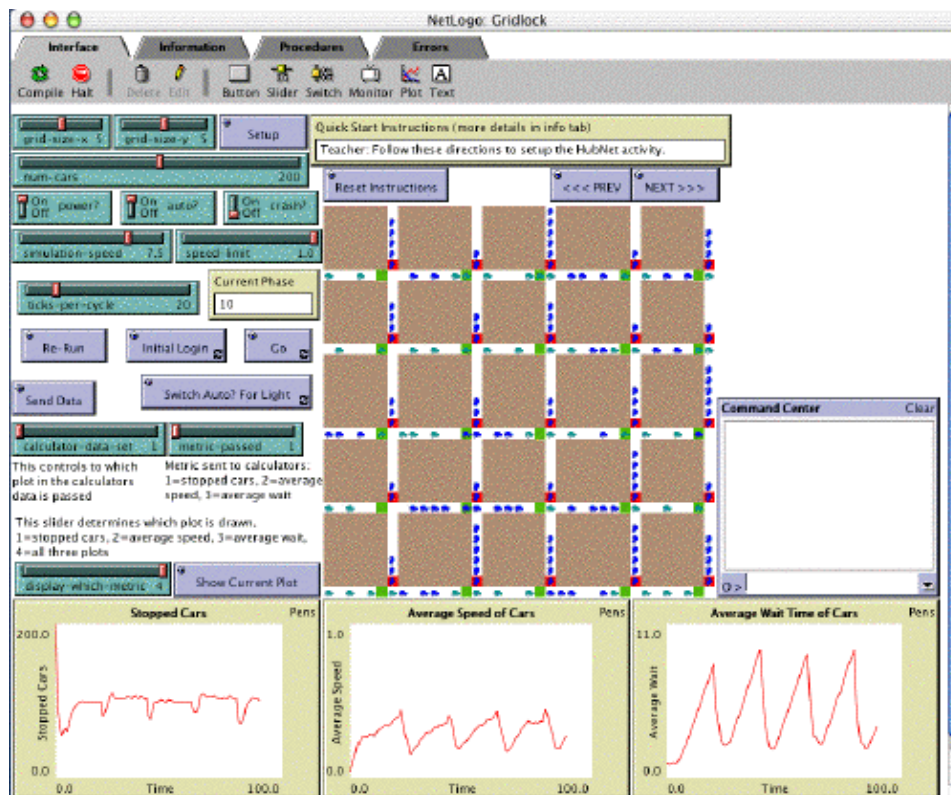
When students are told their intersection they are told using the first quadrant Cartesian coordinates. The traffic light in the lower left hand corner is (0,0), the one above it is (0,1), and the one to the right of it is (1,0). Some teachers have preferred to let the students figure out how this system works, but generally we have tended to tell students that the first number is how many "over" starting from zero and the second number is how many "up" starting from zero. They should see their login number at this intersection. As further confirmation they should select the manual option in the main menu and when the manual mode screen appears, press either ENTER or the CHNG softkey. This should switch their light and they should note how the red and green squares, representing the lights in the respective directions, exchange locations. This is what allows cars to pass in one direction and not in the other.

If there is an intersection that isn't working for some reason, you can "automate" it by pressing the "Revert Light to Unmanned" button, then clicking on the intersection to automate. Repeat this procedure for as many intersections as needed.

Letting the Traffic Go

Once everyone has logged on and found their intersections, press the Initial Login button again to turn it off. You can choose to discuss the different graphical metrics before the students start, but we recommend (pretty strongly, since students will be antsy to assume control of the network) that you wait until after things have run for a while to discuss them. And then we recommend starting a discussion only after you have pressed the Go button again (to turn it off) to stop the traffic flow. While students will become very animated in controlling the traffic, you can encourage them at least a little bit to "notice the graphs" as they are playing.

Remind the students that they are suppose to be improving traffic flow, and press the Go button to let them have at it for a while longer.



At first students will be very focused on their own intersections, then they will tend to become aware of how their intersections are impacted by the ones around them (such that you'll hear them "encouraging" their peers [e.g., "Hey, number 3 turn your light faster!"]) and they might even begin to develop local strategies that they'll work to articulate. As this is going on, you might report a top-level characterization of how they are doing ... "Ooh, things are getting better (worse) ... whatever you all are doing is starting to payoff (or not)."

Depending on how in-control you feel, you might want to have the last 10 - 20 seconds of the first run be with their hands off the calculators. Obviously this will suddenly make the traffic much worse (we expect!) but the contrast will be useful in helping to understand the relationships between the metrics and what it is they measure. Then press the Go button again to stop the flow of traffic.

Discussion of Strategies

A place to start the discussion is to ask students what strategies they used in controlling their traffic light. Some of the strategies we've heard include:

- Turning green in the direction that there are the most stopped cars (we call this the "traffic cop" strategy because it is the one police officers use when directing traffic)
- Turn green in the direction the most cars are coming from
- Follow the light before my intersection (usually students mean vertically)
- Just alternate (sometimes with a counted interval [hinting at what the auto? yes mode is about], sometimes not)

You can also ask if these are strategies that everyone might do (almost all of them are). Also ask if there are other strategies that might be tried as a group. Two of the most common are:

- "Synch the lights" where one turns green, then another, then another. This is a strategy they may have experienced in some cities. Lots of interesting conversation can happen about how to implement this and whether "synch"-ing one direction (e.g., downward) will synch in the other (to the right).
- In a variation of the second strategy above, by anticipating stop the fewest cars.
- Push the students to see if they can generalize some of their earlier strategies.

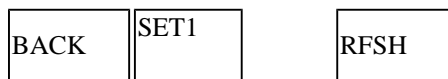
Getting Data Out to the Calculators

It is important that the discussions and analyses of results not always be "centralized." One of the distinctive features of the HubNet design is that it puts powerful functionality in every student's hands so that each of them can become more facile and nuanced in using this functionality to make sense of complex phenomena.

Press the Send Data button in NetLogo. This sends data from the participatory simulation to the server. Now the students have to get this data. The students should return to the Main Menu on the calculator and select the option to View Data. The calculators will retrieve the data set from the server and display it as a statplot on the calculator. You should see the data and softkeys like the following.



You can turn a data set on and off by pressing the softkey corresponding to the data set. So if you pressed the SET1 data key above, this graph would no longer be plotted and you'd see the following for softkeys.



The strike-through means this set is now off. After turning the data set on, pressing the right and left arrow keys moves you through the data set. If more than one data set was displayed, the up and down arrows would move between them. Pressing ENTER returns you to the screen with the softkeys.

You can now send a second data set by moving the slider on the calculator-data-set slider AND the metric passed slider to a new value (say, "2" for the second metric). Press Send Data and have the students press the RFSH softkey. They will be sent the new data set and both data sets will be on.

Because these data sets, unlike those for the Disease participatory simulation, are for different quantities it is likely that it will be hard to see both data sets at the same time. Pressing the softkey associated with which one you'd no longer like to see, will toggle this plot off.

Repeat the send sequence for the third metric (move both sliders in NetLogo; students press refresh).

Discussion of Metrics

All three metrics will now be on the calculators. We have found it valuable to have students work in groups of three at this point, where each student has one of the three sets toggled on and the others off. Then the group can set all three calculators near each other and start to use the right and left arrows to find interesting or recognizable related sections (e.g., at the end, if you had them take their hands off the calculators this should be a recognizable section). All the graphs have the same horizontal time scale and this axis has the same interpretation for all three (the number of "ticks" of the simulation clock from the beginning of the simulation [actually it is sampled, but the sampling is identical]). Comparisons between the calculators in a group at a given time step or series of time steps are possible.

Ask the groups of students to compare the graphs and see how they might be related. The three metrics are:

- Stopped Cars (1)
- Average Speed of Cars (2)
- Average Wait Time of Cars (3)

If they think an increase in one quantity should be related to an increase or decrease in another quantity, they should be able to find this relation in the graphs at a given region of time. Note, too, that two of these quantities are "averages" and one is just a count (Stopped Cars). How might this difference show up in the data? Finally, each group should start to think about which data set is most useful as a metric for the quality of traffic flow. Why? If they think more than one is needed, which ones and why?

Repeating the Simulation

Now that you have discussed possible strategies and metrics, you can rerun the simulation any number of times. If there is one metric you've decided on, you can now collect data using this same metric for different trials (instead of loading the three data sets from one trial as we did above). To do this you'll leave the metric-passed slider alone, and move only the calculator-data-set slider

each time you do a new trial (either before you start the new trial or after, it doesn't matter; then remember to press Send Data to put it on the server for the calculators to get).

Press the Re-Run button to clear out the graph plots. Choose which metrics you want visible on the upfront screen by changing the value of the display-which-metric slider (if you've decided on one you can choose that one, otherwise number "4" will give you all three metrics at the same time).

If you've decided on a strategy, make sure everyone understands it. As it may be easier to make comparisons if you do nearly the same amount of time for each strategy (and the sampling that is happening will be less likely to cause confusion), decide and announce in advance how long you are going to let the simulation go. If the strategy requires some coordination, have the students work this out in advance. If someone is, for example, to "count to ten" make sure someone is appointed. It is preferable if a student is in these specialty roles. So if you do have an extra student, let him or her take up this role. Now press Go and let the students implement the strategy.

Press Go to stop the data collection. Press Send Data. Have the students go out to the Main Menu and then into VIEWDATA to make sure they got the dataset. (You can go right on to the next step, without checking the data, if you are pressed for time).

If there is a second strategy (and/or a third after that), remember to move the calculator-data-set slider (but NOT the metric-passed, if you want the same metric for all three trials). Press Re-Run, make sure students are ready to implement the next strategy and then press Go. Press Go again to stop. Then Send Data and have the students press BACK and then go into view data. The auto mode is an interesting capability and you are encouraged to have students at least think about this as one of the options to try. [If there are more than three strategies, maybe decide which one (or two) are the best so far, and then overwrite the loser with a fourth strategy.]

Now comes the challenge of comparing complex data sets. Let groups of students brainstorm different ways of comparing. Note that the students can now go to the QUIT option in the main menu and press ENTER. If they may want to come back into the software later, choose "USE CALCULATOR" (the server remembers which calculator had which login number and NetLogo will remember which intersection was assigned to which calculator). If you are not planning on having them re-enter the activity, choose LOG OFF. If you did the Use Calculator option and now want back "in", press APPS and then Network as if you were logging in again, but now you'll jump past the login screen and right into the activity. Press Re-Run and make whatever other adjustments you want to make. If you chose Log off and now have decided you really want to go back in, then you'll just need to start from scratch on the Setup sequence.

The datasets are still in the calculator. Press 2nd then STAT to get LIST. This displays the LISTS in the calculator. DATA1, DATA2, and DATA3 are the vertical values and TIME1, TIME2, and TIME3 are, as you might expect, the corresponding time lists. The calculator has a huge set of analysis tools available on it. In addition, students should be encouraged to make up their own forms of analysis that may or may not make use of these tools.

You can structure this analysis in lots of different ways. GraphLink can be used to preserve groups' datasets for the next day (reload one of the calculators from the group with the data and then have them transfer the data between the calculators using the LINK command [2nd then X, T, theta, n]). The analysis can, easily, take a whole period if done thoroughly. At some point students should present their analyses to the class. The purpose of the presentation is to make a recommendation to the Mayor and be able to defend this recommendation. Both the teacher and their peers can evaluate groups on how well they achieve this.

Extensions and Other Things to Try

Try changing the speed limit for the cars. How does this affect the overall efficiency of the traffic flow? Are fewer cars stopping for less time? Is the average speed of the cars higher or lower than before?

Try changing the number of cars on the roads. Does this affect the efficiency of the traffic flow?

How about changing the speed of the simulation? Does this affect the efficiency of the traffic flow?

Using HubNet, try running this simulation with AUTO? being true and AUTO? being false. Is it harder to make the traffic move well using one scheme or the other? Why?

Using HubNet, try running this simulation with AUTO? being true. Try to find a way of setting the phases of the traffic lights so that the average speed of the cars is the highest. Now try to minimize the number of stopped cars. Now try to decrease the average wait time of the cars. Is there any correlation between these different metrics?

Time Considerations

2 to 4 days

Curriculum Standards

From the NCTM standards -

- Data Analysis and Probability -
 - Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
- Problem Solving -
 - solve problems that arise in mathematics and in other contexts
 - apply and adapt a variety of appropriate strategies to solve problems
- Connections -
 - recognize and use connections among mathematical ideas
 - understand how mathematical ideas interconnect and build on one another to produce a coherent whole
 - recognize and apply mathematics in contexts outside of mathematics
- Representation -
 - use representations to model and interpret physical, social, and mathematical phenomena

Curriculum Objectives

As the students decide upon various metrics, they form connections between the model and the mathematics they decide to use. They will also try several strategies, and have the opportunity to tie together many ideas from mathematics and social analyses of behavior and preference.

Support Resources in NetLogo

These are resources that are included in the HubNet Gridlock model.

QuickStart Instructions

- Teacher: Follow these directions to setup the HubNet activity.
- Optional- Zoom In (see Tools in the Menu Bar) - optional
- Change the traffic grid (using the sliders GRID-SIZE-X and... GRID-SIZE-Y) to make enough lights for everyone.
- Change any other of the settings that you would like to change.
- For example, if you plan on running Gridlock in... the MANUAL mode, be sure to have AUTO? set to OFF.
- Also be sure to set CALCULATOR-DATA-SET and... METRIC-PASSED to the appropriate values.
- Press the SETUP NetLogo button.
- Press the INITIAL LOGIN button.
- Everyone: Reset the RAM on your calculator (2nd MEM 7 1 2).
- Login to the calculator.
- Teacher: Once everyone is at the calculator Main Menu... stop the INITIAL LOGIN button by pressing it again.
- Everyone: Whichever mode AUTO? is set for in NetLogo,... choose that option on the calculators at the calculator Main Menu.
- If you have chosen MANUAL,...
- you can change the state of your light by pressing... ENTER or the SWCH softkey on the calculator.
- If you have chosen AUTO,...
- you can change the phase of your light by pressing... a number in the range 00-99.
- Teacher: Once everyone is in the appropriate section,... start the simulation by pressing the GO button.
- Everyone: After a while of running the simulation,... you may want to view the data that NetLogo could send.
- Press the BACK softkey to return to the Main Menu.
- Teacher: Once everyone is back in the calculator Main Menu... press the NetLogo GO button to stop it.
- Make sure that CALCULATOR-DATA-SET and METRIC-PASSED... are set to the appropriate values that you want to... send to the calculators.
- Press the SEND DATA button.
- Everyone: To view the data sent to the calculators,... choose the VIEW DATA option.

- Teacher: To send different data to the calculators,... change the values of CALCULATOR-DATA-SET and... METRIC-PASSED and press the SEND DATA button.
- Everyone: To collect more data, choose the... calculator menu option that corresponds to... the AUTO? switch and continue.
- Teacher: Start the model by pressing the NetLogo GO button.
- To change the mode of AUTO?,...
- Everyone: Exit to the calculator Main Menu.
- Teacher: Change the value of AUTO?.
- Press the NetLogo RE-RUN button.
- Everyone: Whichever mode AUTO? is now set for in NetLogo,... choose that option on the calculators at the calculator Main Menu... and continue.
- To change the metric plotted in NetLogo,...
- Select the CHOOSE METRIC option at the calculator Main Menu.
- Press 1 to see the STOPPED CARS plot, 2 for... the AVERAGE SPEED plot, 3 for the AVERAGE WAIT plot, and... 4 for all three plots.
- Teacher: To rerun the activity with the same group,... do not clear the server.
- Everyone: Exit to the calculator Main Menu.
- Teacher: In NetLogo, press the NetLogo GO button, if it is on.
- Change the values of the sliders and switches to... the values you want.
- Press the RE-RUN button.
- Everyone: Choose the appropriate option from... the calculator Main Menu based on the value of AUTO?.
- Teacher: Once everyone is in the appropriate section,... restart the simulation by pressing the GO button.
- Teacher: To start the simulation over with a new group,... stop the model by pressing the NetLogo GO button, if it is on.
- Have everyone, including yourself, logout of their calculators.
- Press the ERASE ALL DATA button on the TISCHOOL site.
- Press the NetLogo SETUP button.
- Follow these instructions from the beginning again.

Information Tab

WHAT IS IT?

Students control traffic lights in a real-time traffic simulation. The teacher controls overall variables, such as the speed limit and the number of cars. This allows students to explore traffic dynamics, which can lead into many areas of study, from calculus to social studies.

Challenge the students to develop strategies to improve traffic and discuss the different ways to measure the quality of traffic.

The coordinates for the traffic lights are based on the first quadrant of the Cartesian plane. Therefore, the traffic light with the coordinates (0,0) is in the lowest row and the left-most column. The traffic light above it has coordinates (0,1) and the traffic light to the right of it has (1,0).

This activity requires the TI Navigator activity AAA - Gridlock 1.2

For further documentation, see the Participatory Simulations Guide found at <http://ccl.northwestern.edu/ps/>

HOW TO USE IT

QUICKSTART INSTRUCTIONS:

Contains instructions as to how to quickly setup the model, calculators, and TISchool web page so as to run this activity. The instructions can be found below:

Teacher: Open the TISchool site in your web browser.
 Enable activity AAA - Gridlock 1.2
 Open the teacher console and press the ERASE ALL DATA button.
 If it is not open already, open the NetLogo model.
 If you are prompted by a Login dialog, enter your teacher id and password and any other necessary information.
 Optional- Zoom In (see Tools in the Menu Bar)
 Change the traffic grid (using the sliders GRID-SIZE-X and GRID-SIZE-Y) to make enough lights for everyone.
 Change any other of the settings that you would like to change.
 For example, if you plan on running Gridlock in the MANUAL mode, be sure to have AUTO? set to OFF.
 Also be sure to set CALCULATOR-DATA-SET and METRIC-PASSED to the appropriate values.
 Press the SETUP NetLogo button.
 Press the NetLogo INITIAL LOGIN button.

Everyone: Reset the RAM on the calculator by pressing the following keys:
 2nd MEM 7 1 2.
 Login to the calculator.

Teacher: Once everyone is at the calculator Main Menu, stop the INITIAL LOGIN button by pressing it again.
 If there are extra intersections that are not associated with a calculator, they will switch automatically at the beginning of each cycle.

Everyone: Whichever mode AUTO? is set for in NetLogo, choose that option on the calculators at the calculator Main Menu.
 If you have chosen MANUAL, you can change the state of your light by pressing ENTER or the CHNG softkey on the calculator.
 If you have chosen AUTO, you can change the phase of your light by pressing a number in the range 00-99.

Teacher: Once everyone is in the appropriate section, start the simulation by pressing the GO button.

Everyone: After a while of running the simulation, you may want to view the data that NetLogo could send.
 Press the BACK softkey to return to the Main Menu.

Teacher: Once everyone is back in the calculator Main Menu press the NetLogo GO button to stop it.
 Make sure that CALCULATOR-DATA-SET and METRIC-PASSED are set to the appropriate values that you want to send to the calculators.
 Press the SEND DATA button.

Everyone: To view the data sent to the calculators, choose the VIEW DATA option.

Teacher: To send different data to the calculators, change the values of CALCULATOR-DATA-SET and METRIC-PASSED and press the SEND DATA button.

Everyone: To collect more data, choose the calculator menu option that corresponds to the AUTO? switch and continue.

Teacher: Start the model by pressing the NetLogo GO button.

To change the mode of AUTO?,

Everyone: Exit to the calculator Main Menu

Teacher: Change the value of AUTO?.

Everyone: Whichever mode AUTO? is now set for in NetLogo, choose that option on the calculators at the calculator Main Menu and continue.

To change the metric plotted in NetLogo,
 Select the CHOOSE METRIC option at the calculator Main Menu.
 Press 1 to see the STOPPED CARS plot, 2 for the AVERAGE SPEED plot, 3 for
 the AVERAGE WAIT plot, and 4 for all three plots.

To rerun the activity with the same group,
 Teacher: Do not clear the server.
 Everyone: Exit to the calculator Main Menu.
 Teacher: In NetLogo, stop the GO button if it is on by pressing it.
 Change the values of the sliders and switches to the values you want.
 Press the RE-RUN button.
 Everyone: Choose the appropriate option from the calculator Main Menu based
 on the value of AUTO?.
 Teacher: Once everyone is in the appropriate section, restart the simulation
 by pressing the GO button.

To start the simulation over with a new group,
 Teacher: Stop the model by pressing the NetLogo GO button, if it is on.
 Have everyone, including yourself, logout of their calculators.
 Press the ERASE ALL DATA button on the TISCHOOL site.
 Press the NetLogo SETUP button.
 Follow these instructions from the beginning again.

BUTTONS:

SETUP - generates a new traffic grid based on the current GRID-SIZE-X and
 GRID-SIZE-Y and NUM-CARS number of cars. This also clears all the plots.
 This should only be pressed when starting out with a new group of users
 since all users associated with a traffic light will be disassociated from
 that traffic light.

RE-RUN - allows you to keep the current traffic light/calculator
 associations, but clears the plots and after deleting all the currently
 existing cars, creates NUM-CARS number of cars. This does not change the
 grid size. This should be used to setup the model again for collecting more
 data or running the model again with the same users connected.

GO - runs the simulation indefinitely

SEND DATA - sends the data accrued in the list specified by METRIC-PASSED to
 the calculator data set specified by CALCULATOR-DATA-SET. Further, if the
 list sent is larger than a maximum value, the list that is sent is
 "sampled." This means that items are removed from the list that is sent in
 a periodic manner so until there is at most the maximum number of elements.
 Sampling is necessary since the calculator can only handle a certain amount
 of data.

INITIAL LOGIN - allows users to log into the activity without running the
 model or collecting data

REVERT LIGHT TO UNMANNED - allows you to force a light to begin switching
 automatically. This is handy when a calculator drops its connection and the
 corresponding light is holding up traffic.

NEXT >>> - shows the next quick start instruction

<<< PREVIOUS - shows the previous quick start instruction

RESET INSTRUCTIONS - shows the first quick start instruction

SLIDERS:

SPEED-LIMIT - sets the maximum speed for the cars

NUM-CARS - the number of cars in the simulation (you must press the SETUP or
 RE-RUN buttons to see the change)

SIMULATION-SPEED - the speed at which the simulation runs

TICKS-PER-CYCLE - sets the maximum value that the phase can be. This has no

effect when the model is run with AUTO? false. Also, the phase that each user chooses is scaled to be less than or equal to this value.

GRID-SIZE-X - sets the number of vertical roads there are (you must press the SETUP button to see the change)

GRID-SIZE-Y - sets the number of horizontal roads there are (you must press the SETUP button to see the change)

CALCULATOR-DATA-SET - the number of the graph in the calculator to which the current data will be sent and displayed on the calculators when the VIEW DATA menu option is chosen

METRIC-PASSED - determines which plot data to send to the calculators. 1 = the data from STOPPED CARS, 2 = the data from AVERAGE SPEED OF CARS, 3 = the data from AVERAGE WAIT TIME OF CARS

DISPLAY-WHICH-METRIC - determines which plot is drawn in NetLogo. 1=STOPPED CARS, 2=AVERAGE SPEED OF CARS, 3=AVERAGE WAIT TIME OF CARS, 4=all three plots. It should be noted that if this is 4, the calculators cannot change this value.

SWITCHES:

CRASH? - toggles car crashing

POWER? - toggles the presence of traffic lights

AUTO? - toggles between automatic mode, where the students' lights change on a cycle, and manual in which students directly control the lights with their calculators. Lights which are not associated with students always change on a cycle.

PLOTS:

STOPPED CARS - displays the number of stopped cars over time

AVERAGE SPEED OF CARS - displays the average speed of cars over time

AVERAGE WAIT TIME OF CARS - displays the average time cars are stopped over time

CALCULATOR INFORMATION

TEACHER CALCULATOR:

Students and teacher have identical calculator programs.

STUDENT CALCULATOR:

After logging in, in the calculator Main Menu it is possible to choose between manual and automatic mode. IMPORTANT!! The mode selected needs to match with the mode chosen in the NetLogo model via the AUTO? switch. In MANUAL mode, press ENTER or the CHNG softkey to switch the state of the light you control. In AUTO mode, enter the phase for your light. The phase must be in the range 0-99.

You can also choose to view plot data passed back to the calculators by choosing the VIEW DATA option. Be sure that data has been sent to the calculators by pressing the SEND DATA button in NetLogo first.

It is possible to pick which metric is plotted in the NetLogo plots by choosing the CHOOSE METRIC option. Press the number 1 to show the STOPPED DATA plot, 2 to show the AVERAGE SPEED OF CARS plot, 3 to show the AVERAGE WAIT TIME OF CARS plot, or 4 to show all three plots simultaneously. It should be noted that if this is 4, the calculators cannot change this value.

THINGS TO NOTICE

When cars have stopped at a traffic light, and then they start moving again, the traffic jam will move backwards even though the cars are moving forwards. Why is this? Discuss in your class possible reasons for this phenomena.

THINGS TO TRY

Try changing the speed limit for the cars. How does this affect the overall efficiency of the traffic flow? Are fewer cars stopping for a shorter amount of time? Is the average speed of the cars higher or lower than before?

Try changing the number of cars on the roads. Does this affect the efficiency of the traffic flow?

How about changing the speed of the simulation? Does this affect the efficiency of the traffic flow?

Using HubNet, try running this simulation with AUTO? being true and AUTO? being false. Is it harder to make the traffic move well using one scheme or the other? Why?

Using HubNet, try running this simulation with AUTO? being true. Try to find a way of setting the phases of the traffic lights so that the average speed of the cars is the highest. Now try to minimize the number of stopped cars. Now try to decrease the average wait time of the cars. Is there any correlation between these different metrics?

EXTENDING THE MODEL

Currently, the maximum speed limit (found in the SPEED-LIMIT slider) for the cars is 1.0. This is due to the fact that the cars must look ahead the speed that they are traveling to see if there are cars ahead of them. If there aren't, they speed up. If there are, they slow down. Looking ahead for a value greater than 1 is a little bit tricky. Try implementing the correct behavior for speeds greater than 1.

The way that NetLogo samples the data lists sent to the calculators is a very simple method of sampling lists. Try implementing a more complicated way of sampling the lists. For instance, you could sample a small portion of the list.

CREDITS AND REFERENCES

This activity and associated models and materials was created as part of the project: PARTICIPATORY SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. The project gratefully acknowledges the support of the National Science Foundation (REPP program) -- grant number REC #9814682.

Copyright 1999 by Uri Wilensky & Walter Stroup. Updated 2001,2002. All rights reserved.

Permission to use, copy, or modify this software and its associated

documentation, models and curricular materials for educational and research purposes only and without fee is hereby granted, provided that this copyright notice and the original authors' names appear on all copies and supporting documentation. For any other uses of this software, in original or modified form, including, but not limited to distribution in whole or in part, specific prior permission must be obtained from Uri Wilensky and Walter Stroup. These programs shall not be used, rewritten, or adapted as the basis of a commercial or hardware product without first obtaining appropriate licenses from Uri Wilensky & Walter Stroup. We make no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

To refer to this model in academic publications, please use: Wilensky, U. & Stroup, W. (1999). NetLogo HubNet Gridlock model.
<http://ccl.northwestern.edu/netlogo/models/HubNetGridlock>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

In other publications, please use: Copyright 1999 by Uri Wilensky and Walter Stroup. All rights reserved. See
<http://ccl.northwestern.edu/netlogo/models/HubNetGridlock> for terms of use.

Equipment/Materials Needed:

- TI Navigator System
- NetLogo Software
- NetLogo model: Gridlock.nlogo
- Personal computer
- Projection System (for teacher calculator and computer)
- TI HubNet Activity: AAA - Gridlock 1.2

Keywords

- Model
- Emergence
- Traffic
- Measurement
- Metric
- Phase
- Average

Elevators

Subject Area

Mathematics, Science

Topics

- Rate and Amount
- Graph Interpretation
- Slope
- Addition of Signed Integers
- Area Model of Multiplication

- Derivative and Integral
- Modeling

Abstract/Summary

Like the function activity, there are lots of different ways and places in the math or science curriculum where the elevators activity can be used. Much of the core functionality and the idea of using "delta blocks" as a way into students making sense of rate-related graphing comes from prior work by the SimCalc Project (one of the authors of these materials was a researcher on that project)³. The key difference in this context is leveraging the group capabilities of the HubNet system and in particular the flexibility of using NetLogo as a scripting language. Emergent patterns of motion develop from the interaction of students' individual graphs and overall patterns in the motion of the elevators on the up-front display space.

The goal of this activity is for students to begin to make sense of the relationship between graphical renderings of rate - the velocity of the elevator - and amount - which floor the elevator is on. Delta blocks are blocks of area "under" a velocity time graph. Students build understanding by literally building "walls" and transferring these walls onto a velocity time graph to see how differently shaped walls result in different motions of a simulated elevator. A second goal is to be able to see connections between what is often thought of as basic math (e.g., signed addition of delta blocks or area models of multiplication) and advanced mathematics like calculus. Teachers we've worked with have been most enthusiastic about how this approach actually uses calculus ideas - for example, the area "under" a velocity graph - to help teach basics! A third goal is to use the complexity of varying rates and many elevators moving together as a starting place for making sense of rate. Rather than starting with a simple constant rate for one elevator and then having students build from this simplicity to the complexity, this approach uses the texture of varying rate (differently shaped "walls", as introduced below) and many elevators moving in parallel to make sense of rate in general and of constant rate (e.g. $y = mx + b$, where m is a rate) as a "special" or limited case (where the delta-blocks wall is of a constant height). It is important to emphasize that this delta-blocks approach has been extensively tested in some of the most economically challenged schools in the United States (and in Mexico as well) and used successfully with learners as young as third graders (even younger in some cases). While there are lots of ways of starting this HubNet activity we have found that starting with physical blocks and building "real" walls is very important. There is an urge to "skip" this introduction, especially with older students. This has almost always turned out to create problems down the road. The elevators activity can be used in elementary mathematics, pre-Algebra and Algebra (where you explore linear functions AFTER doing more complex motions and students have a solid feel for the distinction between what the "m" and "b" might represent), geometry (you'll probably want to download the free MathWorlds software so as to be able to make more complex areas like triangles, and trapezoids), Algebra II, and, of course, Pre-Calculus and Calculus. Science teachers can use these activities to help with graph interpretation and to help support learning that area under a curve can represent a change in some quantity (e.g., change in position under a velocity-time graph [kinematics], change in momentum for area under a force-time graph, or work for area under a force-position graph and so on).

Prerequisites

Counting

Teacher Notes/Procedures

Introduction and Overview

There are many, many ways of starting this activity. We will present an approach (the delta-blocks approach) that has worked with the largest portion of students (nearly all we've worked with) across the widest range of grade levels and ability. Another more direct, Zen-like approach that we've also seen used successfully is to very briefly introduce the calculator interface and then simply tell everyone, "Find a way to get your elevator to the fourth floor and then SEND this graph to the upfront screen." You can then iterate by saying, "Okay, now start off on a floor other than zero and get to the fourth floor (then, use 8 blocks and get to the fourth floor and so on)." We very much like the problem solving, figure-it-out-yourself feel to this approach, but our experience has been that some fraction of the learners will have difficulty and so if you do just "jump in" this way, be ready to be careful about making sure everyone finds their way "into the game."

Using the delta-blocks approach students begin by building velocity "walls" that control the motion of an elevator. The student handouts are included below. Follow the QuickStart directions to begin the activity. Even though the network is active, using the trajectory outlined below the students start off working individually and then move to using the network functionality. At any point, even if just to show where they're heading, students can send whatever graphs they are working on to the server just to see how their graphs will actually control one of the upfront elevators.

The "delta-blocks" approach to the mathematics of change and variation builds from emphasizing the arrangements of "blocks" of area under a velocity graph. Students use arrangements of delta-blocks to come to an understanding of what a wall being "higher" or "lower" in specific regions means for the motion of a simulated elevator and of what, in a calculus class, would be referred to as the "area under a curve" means for the change (the "delta" of delta blocks) in position of the elevator. They also develop a sophisticated notion of additive inverse related to blocks of area "above" the axis "canceling" with blocks of area "underneath" the axis. Later in the activity the students can compare their velocity wall (or graph) to a corresponding position-time graph, by toggling between them. The sequence of activities familiarizes students with the interface and has them explore various challenges with complex motion (where velocity changes).

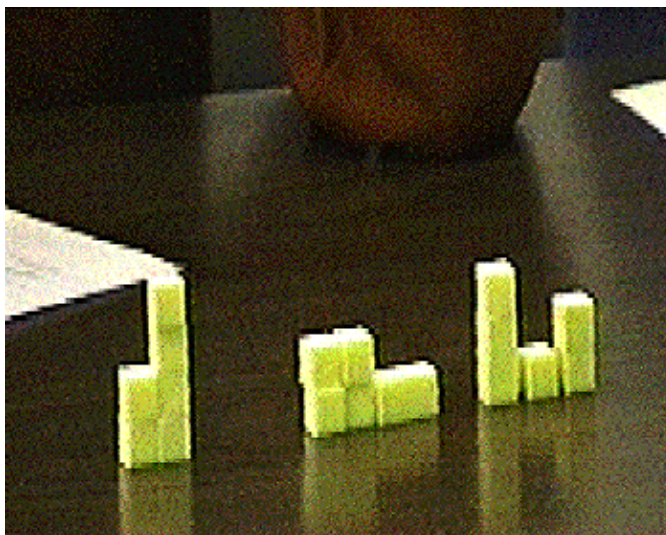
Some of the challenges have students create graphs with some portions of the velocity graphs being the same. They should see that in these regions the elevators "move the same" even if they are in different places. To introduce the idea of "solving" (as it is discussed in Algebra), challenges are given where portions of the position-time graphs are the same or where the graphs are all to go through a particular point. In these regions where the position-time graphs are identical, the elevators are "all in the same place and moving the same"; where there is just a point in common they are all at the same floor at this point but otherwise may be in very different locations.

If you want to return to the special linear case students can be asked to create constant velocity graphs so as to generate linear position-time graphs. With the velocity "walls" associated with linear position graphs forming a rectangle, connections can easily be made to the area model of multiplication in a rate-based context (rate [height] * time [width] = change in position [area]). Computing a slope can be seen as solving for the height of the wall, given the area (change in position) and the base (the change in time). On a position-time graph, this change in position divided by the change in time is the definition of slope or what the students will start off calling "steepness." Thus a connection is made between slope, what it represents, and the various ways of computing it. Slope is also clearly distinguished in children's thinking from the "y-intercept" or, in the elevator context, where the elevator starts off. Additionally, the idea of solving for x can be associated with finding where two elevators are at the "same place" or same floor. Again this follows up on the more complex challenges related to sharing regions or points that are mentioned above. Start with these more interesting and textured cases to help students make better sense of the simple, more uniform case of linear functions.

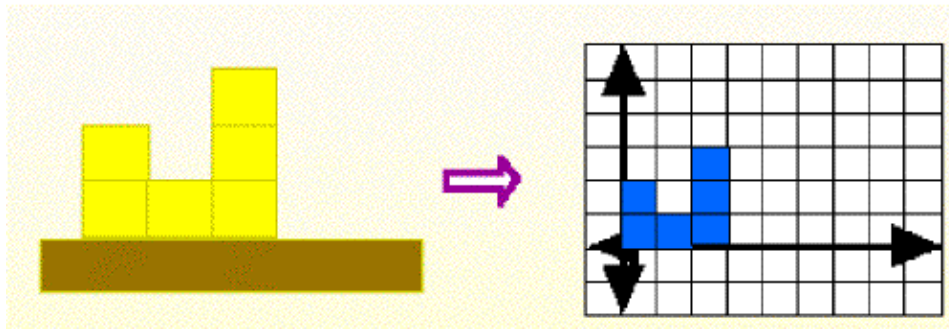
Overall the activity starts with building walls, has students transfer the walls to the simulations software to see how they "control" the elevator, moves on to some individual challenges, and then jumps to explorations involving using the network and being able to see everyone's elevators moving at the same time. Copies of the Handouts should be given to each student but you can always conserve paper by having them write/draw in their notebooks or simply jump to transferring the walls right into the software (and then describing the motion they see).

Starting with Building Physical Walls

The Handout takes students through the construction of two physical walls using 6 blocks each. Walls should be built vertically, blocks should not be hidden behind the wall, and blocks should be placed (vertically) directly on top of each other (no straddling or arches).



Students should sketch a side view of each of their walls.



You'll need to provide an introduction to using the calculator software. If you haven't started up the network, do so now and have students login, etc. Follow the QuickStart directions.

When the students log in you should take them through how to use the software. The handout has directions as well so what follows is included as background.

How to Edit the Graphs and Run the Elevator

The following describes how to enter these walls by using the programs that reside in the calculator. Students and teacher have identical programs that use the following keys:

To change the initial floor for the elevator press 0 or LEFT/RIGHT arrow until 0 is indicated as the selected interval in the upper left corner of the screen.

To change the velocity during a time interval, press the number of the interval (1-9) or LEFT/RIGHT arrows until that interval is indicated as the selected interval in the upper left corner of the screen. Then press UP/DOWN to adjust the value.

To change the duration of a time interval, select that interval. Then press 2ND + LEFT/RIGHT to make the interval shorter/longer by half a second. Intervals default at one unit of time long (roughly a second), and can range from .5 to 3. [Note: half intervals currently will not show in the graphics window of NetLogo].

To view the motion of the elevator, select the GO softkey.

To toggle your display between the velocity vs. time graph and the position vs. time graph, press the DISP softkey.

To send your motion to the class and to NetLogo, press the SEND softkey.

To view the class' set of motions individually, press the GET softkey. The first graph sent will then appear on your screen. To cycle through all the solutions, press ALPHA + LEFT/RIGHT. Each solution can be edited on your calculator.

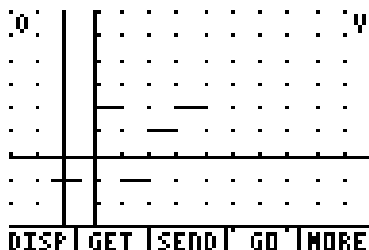
To toggle between sets of softkey menu options, press the MORE softkey.

To restore your solution, press the RCLL softkey (which is on the second menu, accessible via the MORE softkey)

To clear your current graph, press the CLR softkey.

To quit the activity, press the QUIT softkey. The program will ask you to verify that you would like to quit.

After entering a graph, the screen will look something like the following.



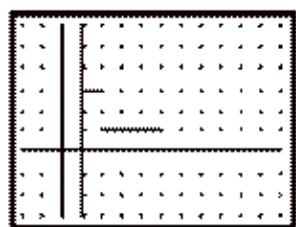
The delta-blocks are the blocks of area between the graph and the axis. For example, in the first interval there are two delta-blocks (imagine shading-in the area under the piece-wise constant velocity segment). There is one negative block in the next interval (students will discover these later on), one positive block in the next, and so on. Because the elevator is shown starting one floor "in the basement" the final location of the elevator is this initial position plus the sum of the delta-blocks: $-1 + 2 + -1 + 1 + 2$ is 3.

The students should use these handout instructions and enter in their walls. This is designed to allow them to become comfortable with the interface, and then start to try to understand how the wall and the elevator's motion are connected. Later in the activity they should press the "DISP" key and look at the position-time graph. When they first do this, you may want to just ask the students what this graph represents. See if they can figure out how the two graphs are connected to each other and to the elevator's motion.

Students will say things like the first graph shows how fast the elevator moves and how much it goes up by (the delta blocks). The second graphs tells "where it's at" or "what floor it's on."

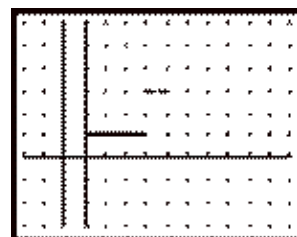
Where to Begin in Class with the Simulation Software

To introduce the calculator interface to students in class you may want to start with jointly entering the following "walls" and discussing what happens when you press the GO softkey. Questions like: How many delta-blocks are there?, Where did the elevator start and stop?, How did it move (fast/slow) and where?, and even how many floors did it go fast/slow for?



Screen from Calculator Math Worlds

The delta-block arrangement



Screen from Calculator Math Worlds

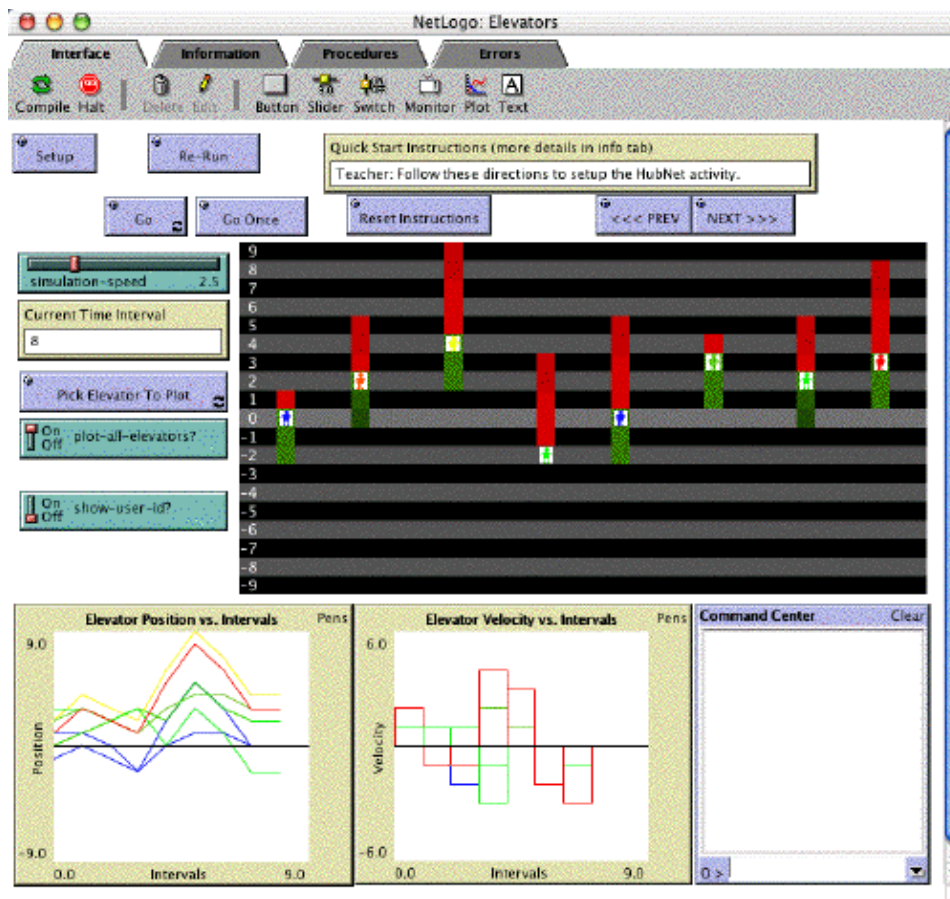
The delta-block arrangement



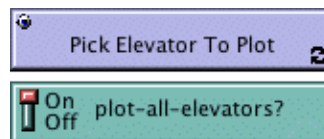
Students will start to notice the pattern that a "higher" wall is faster; "lower" is slower and that the number of blocks is related to how far the elevator goes. Push the students to be as clear about what happens as possible.

Now let them enter their own graphs. Ask them to predict for themselves what will happen. Then run the simulation and write the description on their handouts.

They can, if you want, send up their wall by pressing the SEND key.



Ask them if they can find themselves. You can use the following NetLogo button and switch to focus in on one graph at a time:



Note that the switch has to be off to look at a single graph (and on again to see them all). This feature is quite powerful since the graphs can become quite crowded.

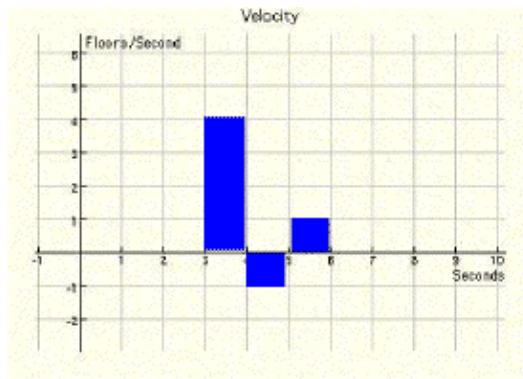
Moving through the Handout

The handout has a series of challenges of quickly increasing difficulty. For our work with younger students we do more activities like the ones in the first homework handout. Start off spending a lot of time asking the students where the elevator will be after one second, two, three and so on. This will help with the transition to understanding the position graph. The position graph, again, is displayed by pressing DISP. Pressing DISP again will bring you back to the velocity graph.

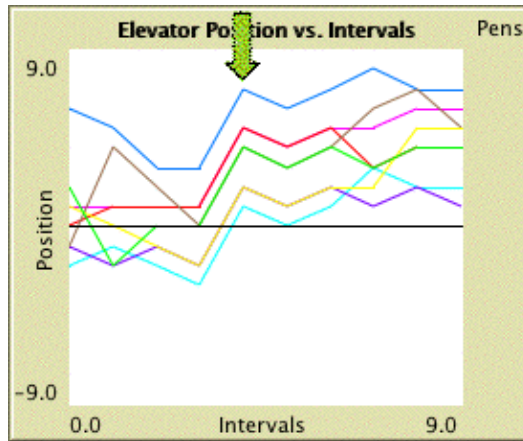
After the first challenge, all of the challenges are designed to create patterns that are interesting in the upfront space. That is, there is something "in common" among all of them that is reflected in the upfront motions and graphs.

For the second challenge, there are two "tricks" for getting to the 4th floor using 6 blocks; either start with the elevator "in the basement" (press 0 and then down arrow) or use blocks under the axes.

Illustrative of the kinds of patterns that will emerge in the upfront space, Challenge 4 requires students to have graphs with the following pattern in common.

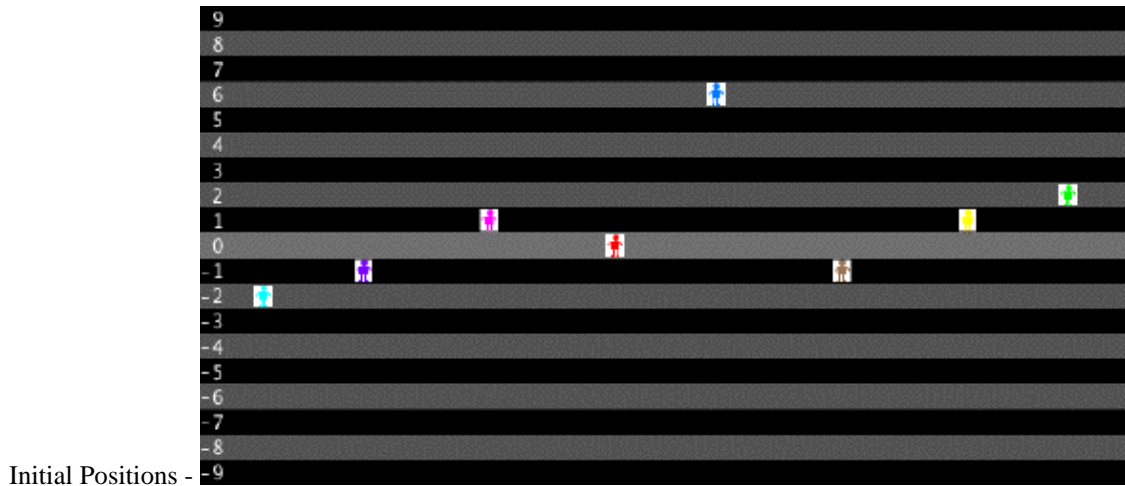


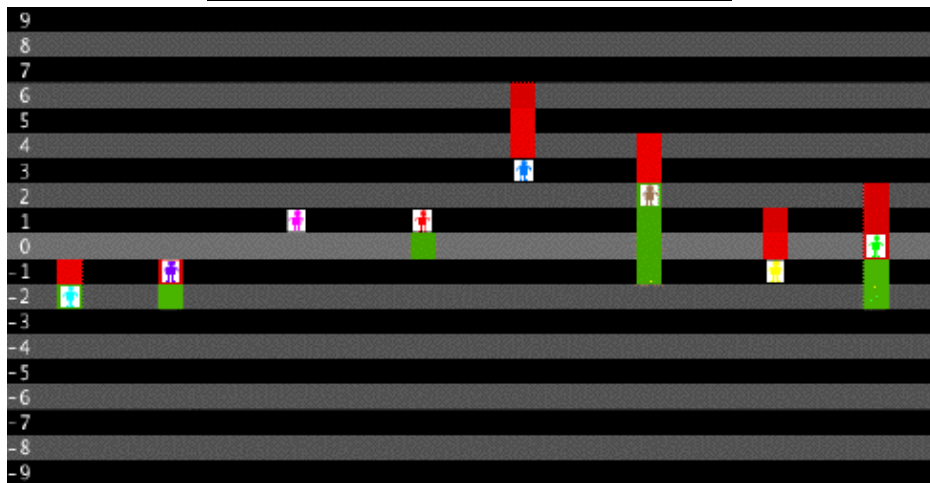
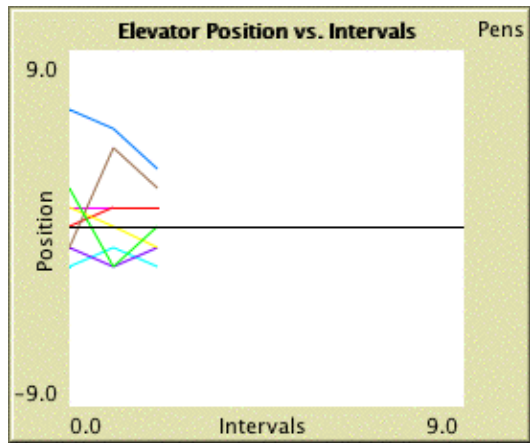
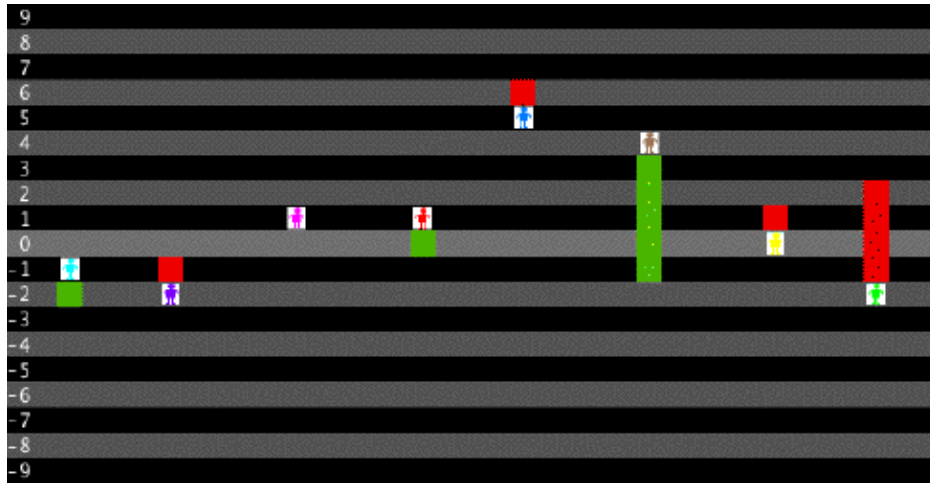
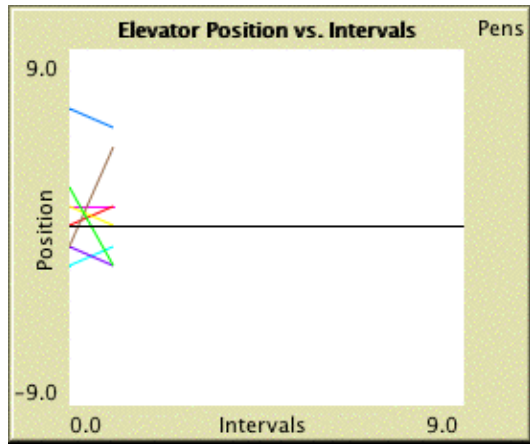
The result of students sending distinct graphs but with this pattern in common is illustrated by the following sequence. Note what happens in the following regions of the graph (corresponding to the blocks shown above).

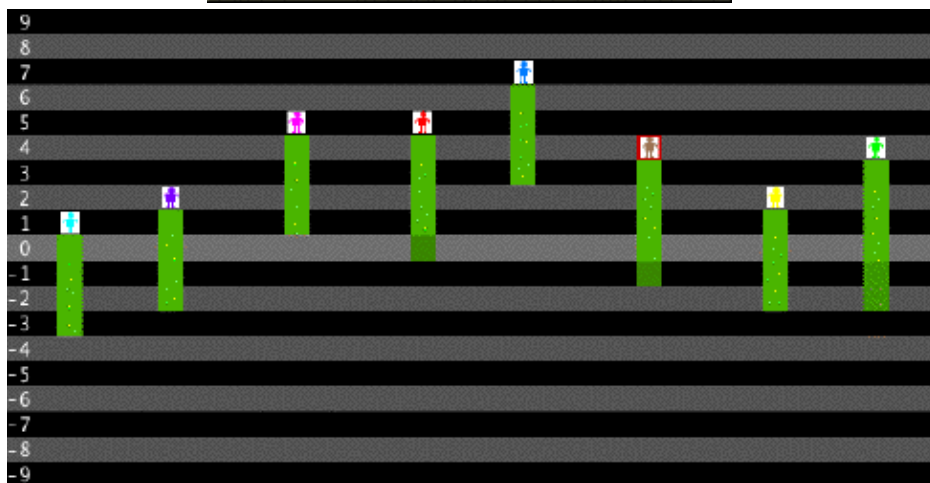
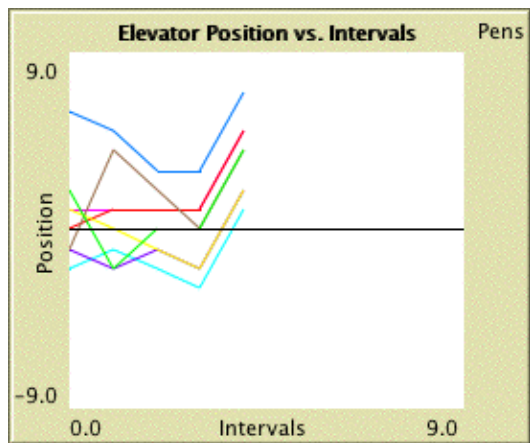
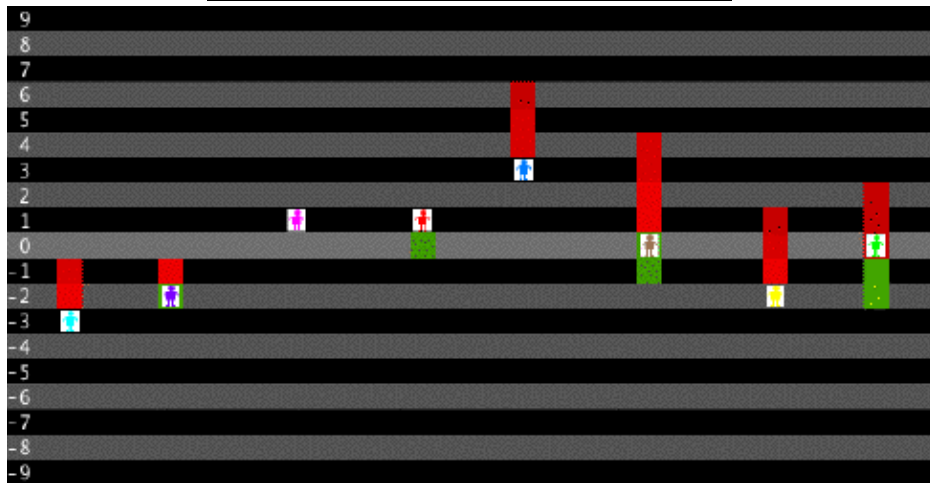
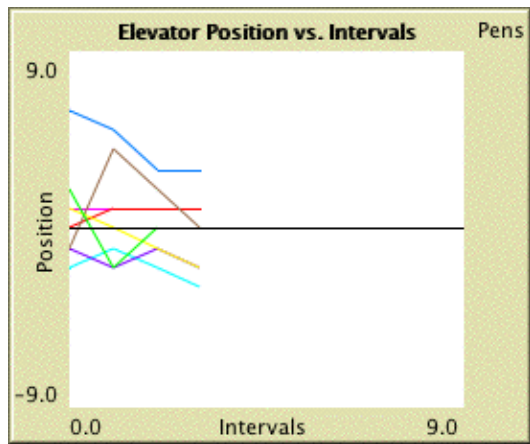


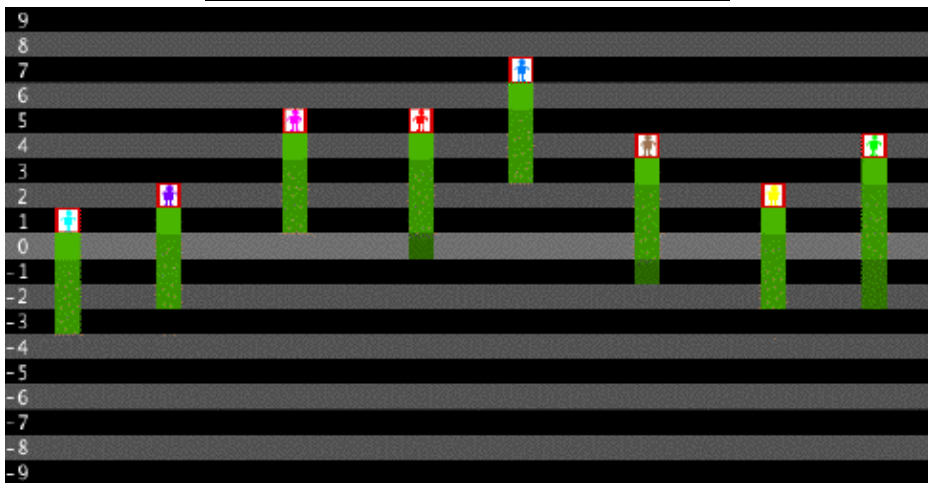
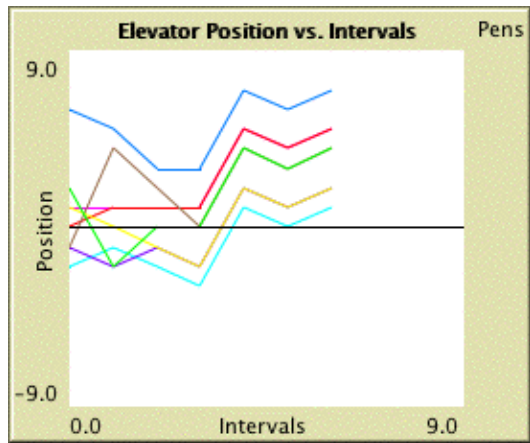
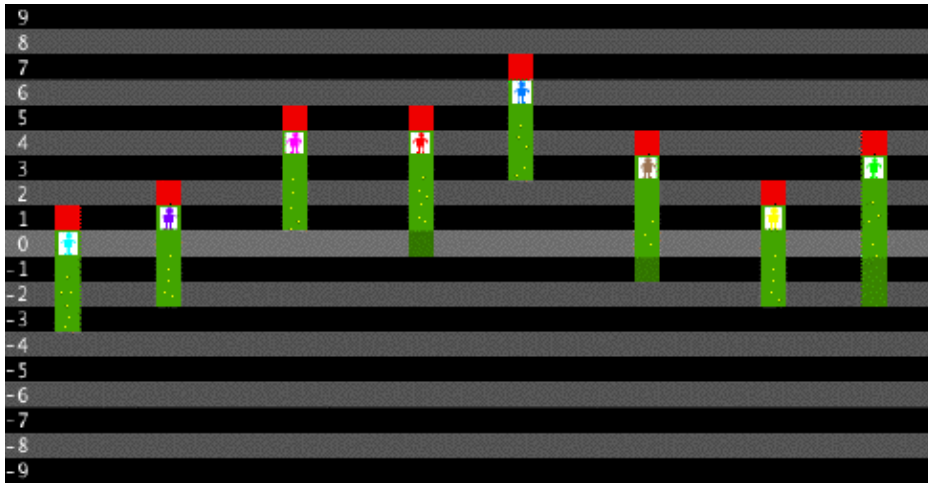
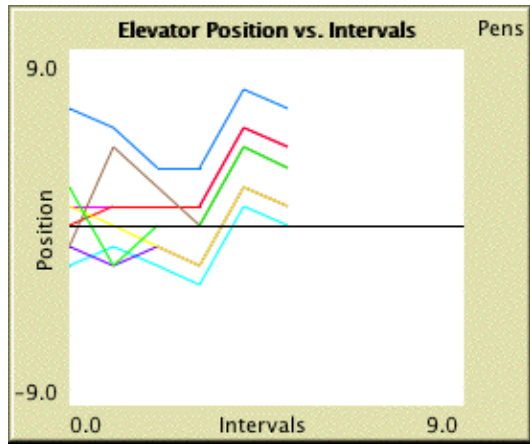
The graphs are parallel. The elevators will all move together in the same directions at the same speeds, but at different positions.

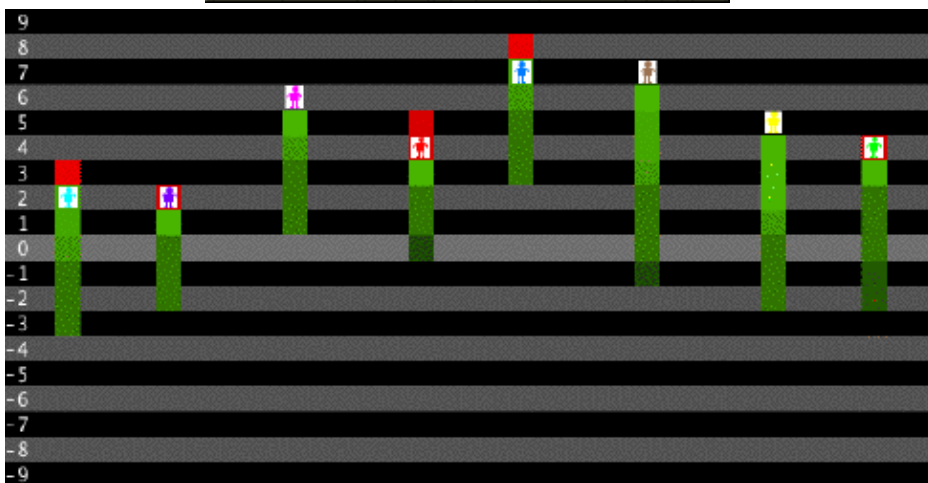
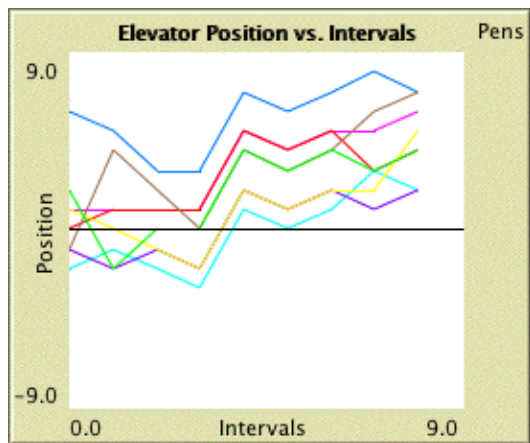
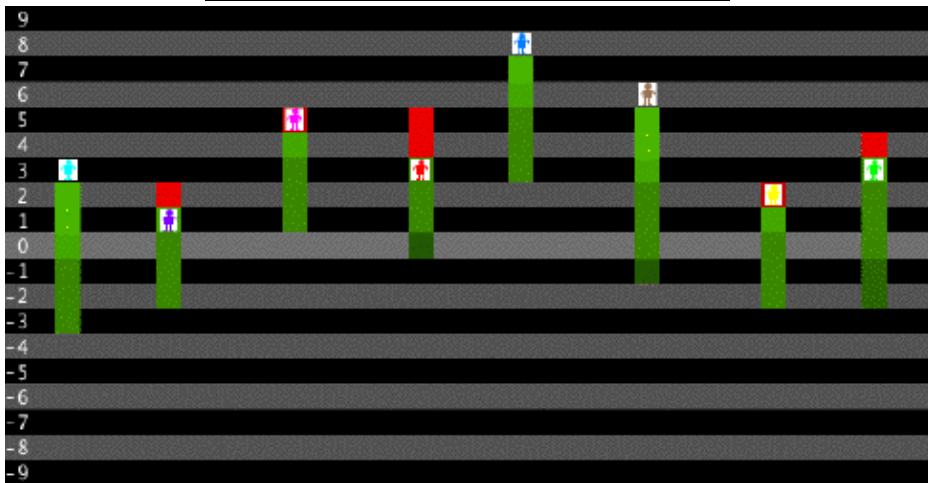
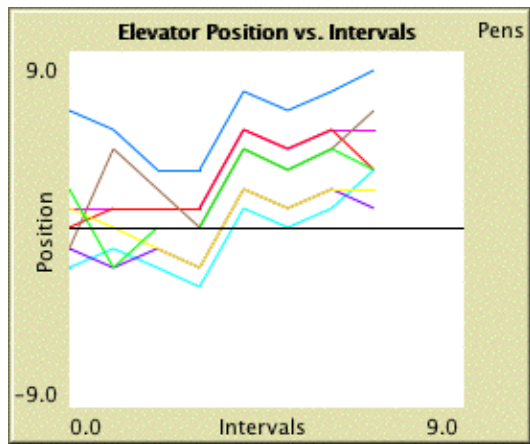
Here is a step-by-step (using Go Once) view of what you'll see upfront. Notice how the elevators moving in the positive direction leave a green trail and those moving in the negative direction leave a red trail. This trail also fades over time.

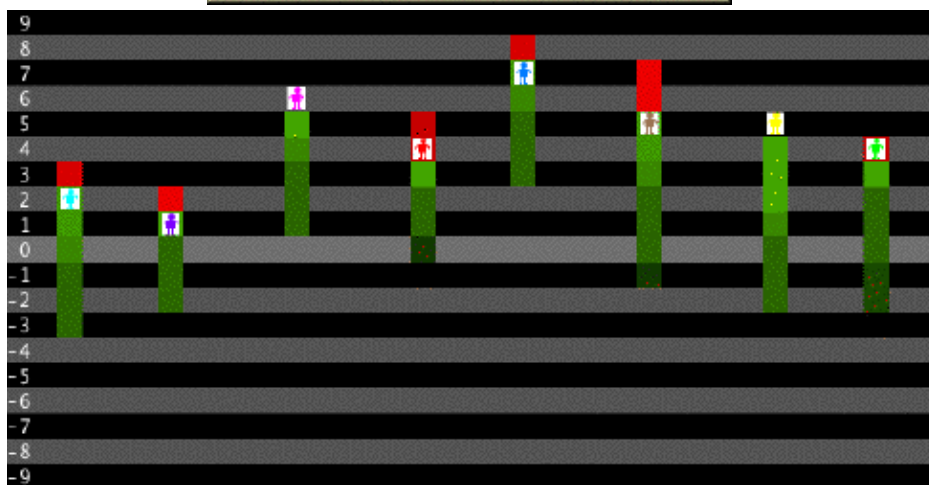
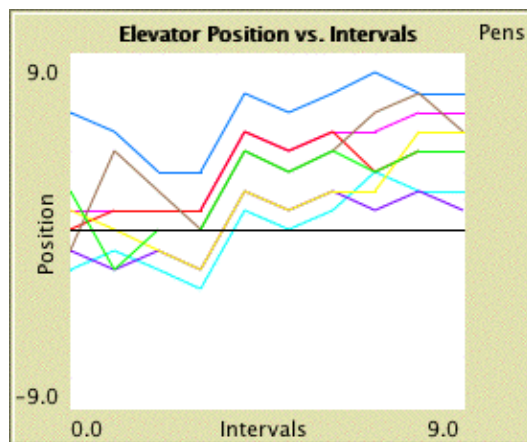












The idea is that for all of the challenges you'll see similar contrasts that will help students understand the graphs.

Homework

These are included (below) to show the kinds of things students could work on at home without the technology.

Time Considerations

This unit was developed for use around 4 class days, and can be easily broken into different sections so as to make it shorter or to target specific concepts.

Curriculum Standards

From NCTM standards, students should learn how to:

- Organize and consolidate their mathematical thinking through communication
- Communicate their mathematical thinking coherently and clearly to peers, teachers and others
- Analyze and evaluate the mathematical thinking and strategies of others
- Use the language of mathematics to express mathematical ideas precisely
- Understand patterns, relations and functions
- Represent and analyze mathematical situations and structures using algebraic symbols
- Use mathematical models to represent and understand quantitative relationships
- Select, apply, and translate among mathematical representations to solve problems
- Use representations to model and interpret physical, social and mathematical phenomena
- Make and investigate mathematical conjectures
- Develop and evaluate mathematical arguments and proofs
- Analyze change in various contexts

Curriculum Objectives

- Through conversation and responses, students can describe to the class the reasoning behind their predictions, and evaluate others strategies for meeting the challenges.
- Through modeling phenomena with analytic functions, students can analyze change and mathematical situations using symbols.
- Through the activity, students can begin to model and interpret physical phenomena using the language of mathematics.

Support Resources in NetLogo

These are resources that are included in the HubNet Elevators model.

QuickStart Instructions

- Teacher: Follow these directions to setup the HubNet activity.
- Optional- Zoom In (see Tools in the Menu Bar) - optional
- Everyone: Reset the RAM on your calculator (2nd MEM 7 1 2).
- Login to the calculators.
- Press ENTER to begin the simulation of the elevators.
- Move around to acquaint yourself with the interface by:
- Pressing the left and right arrows to select different time intervals....
- Pressing the up and down arrows to adjust the velocity of... the elevator for the currently selected interval.
- Press the GO softkey to play the motion described in... the velocity vs. time graph on the calculator.
- Craft individual velocity vs. time graphs on the calculator.
- Then send your graph to NetLogo by... pressing the SEND softkey on the calculator.
- Teacher: Once everyone has sent the graphs,... press the GO button in the NetLogo model.
- Everyone: Once a motion is sent, you can change the motion and... resend it by using the arrow keys and pressing... the SEND softkey again.
- When the graphs are sent to the class and NetLogo,... collect the results via the GET softkey.
- Cycle among the graphs on a calculator by pressing... ALPHA followed by LEFT or RIGHT.
- Teacher: In NetLogo, if you wish to view just one elevator's plots,... press the PICK ELEVATOR TO PLOT button and click on... an elevator in the Graphics Window.... Then set PLOT-ALL-ELEVATORS? to OFF.
- To view another elevator's plots, press... the PICK ELEVATOR TO PLOT button again and click on... another elevator.
- To view all the elevators' plots again, set... PLOT-ALL-ELEVATORS? to ON.
- Teacher: To rerun the activity, do not clear the server.
- Stop the simulation by pressing the NetLogo GO button.
- Optional- Pick a single elevator to watch in the plots and... set PLOT-ALL-ELEVATORS? to OFF. - optional
- Press the RE-RUN button.
- To restart the model, press the GO button.
- Teacher: To start the simulation over with a new group,... stop the model by pressing the NetLogo GO button, if it is on.
- Have everyone, including yourself, logout of their calculators.
- Press the ERASE ALL DATA button on the TISCHOOL site.
- Press the NetLogo SETUP button.
- Follow these instructions from the beginning again.

Information Tab

WHAT IS IT?

In the calculator program, each student defines the motion of an elevator by setting its velocity as a function of time. The students have 9 different intervals for which they can set the velocity of the elevator. They can then send these velocities to NetLogo, where the actions of each elevator can be displayed next to the others. This can serve as a jumping off point for concepts ranging from derivatives and integrals to wave mechanics.

This activity requires the TI Navigator activity AAA - Elevators

For further documentation, see the Participatory Simulations Guide found at <http://ccl.northwestern.edu/ps/>

HOW TO USE IT

QUICKSTART INSTRUCTIONS:

Contains instructions as to how to quickly setup the model, calculators, and TISchool web page so as to run this activity. The instructions can be found below:

Teacher: Open the TISchool site in your web browser.
Enable activity AAA - Elevators.
Open the teacher console and press the ERASE ALL DATA button.

If it is not open already, open the NetLogo model.
If you are prompted by a Login dialog, enter your teacher id and password and any other necessary information.
Optional- Zoom In (see Tools in the Menu Bar)

Everyone: Reset the RAM on the calculator by pressing the following keys:
2nd MEM 7 1 2.
Login to the calculators.
Press ENTER to begin the simulation of the elevators.
Move around to acquaint yourself with the interface. Pressing the left and right arrows to select different time intervals. Pressing the up and down arrows to adjust the velocity of the elevator for the currently selected interval.
Press the GO softkey to play the motion described in the velocity vs. time graph on the calculator.

Craft individual velocity vs. time graphs on the calculator.
Then send your graph to NetLogo by pressing the SEND softkey on the calculator.
Teacher: Once everyone has sent the graphs, press the GO button in the NetLogo model.
Once a motion is sent, you can change the motion and resend it by using the arrow keys and pressing the SEND softkey again.

When the graphs are sent to the class and NetLogo, collect the results via the GET softkey. Cycle among the graphs on a calculator by pressing ALPHA followed by LEFT or RIGHT.
In NetLogo, if you wish to view just one elevator's plots, press the PICK ELEVATOR TO PLOT button and click on an elevator in the Graphics Window. Then set PLOT-ALL-ELEVATORS? to OFF. To view another elevator's plots, press the PICK ELEVATOR TO PLOT button again and click on another elevator. To view all the elevators' plots again, set PLOT-ALL-ELEVATORS? to ON.

Teacher: To rerun the activity, do not clear the server.
Stop the simulation by pressing the NetLogo GO button.
Optional- Pick a single elevator to watch in the plots and set PLOT-ALL-ELEVATORS? to OFF.
Press the RE-RUN button.
To restart the model, press the GO button.

Teacher: To start the simulation over with a new group, stop the model by pressing the NetLogo GO button, if it is on.

Have everyone, including yourself, logout of their calculators.
 Press the ERASE ALL DATA button on the TISCHOOL site.
 Press the NetLogo SETUP button.
 Follow these instructions from the beginning again.

BUTTONS:

 SETUP - clears all turtles, and draws lines marking the floors
 RE-RUN - sets up the model to be able to run with the current elevators and
 with clock set to zero
 GO ONCE - moves the turtles by 1 interval
 GO - receives information from the calculators and runs the simulation
 PICK ELEVATOR TO PLOT - allows the user to pick an elevator to plot the
 velocity and position information for.
 NEXT >>> - shows the next quick start instruction
 <<< PREVIOUS - shows the previous quick start instruction
 RESET INSTRUCTIONS - shows the first quick start instruction

SLIDERS:

 SIMULATION-SPEED - the speed the simulation runs at. The higher the number
 the faster it runs.

SWITCHES:

 PLOT-ALL-ELEVATORS? - if true, the data for all the elevators will be shown
 in the plots. If it is false and if an elevator has been picked by using
 the PICK ELEVATOR TO PLOT button, only the picked elevator's information
 will be shown in the plot from the current time tick forward. Old plot data
 is not erased.
 SHOW-USER-ID? - if true, all the turtles show their user-id as its label.
 If false, no label is shown.

CALCULATOR INFORMATION

TEACHER CALCULATOR:

Students and teacher have identical calculator programs.

STUDENT CALCULATOR:

To change the initial position of the elevator press 0 or LEFT / RIGHT until
 0 is indicated as the selected interval in the upper left corner of the
 screen.

To change the velocity during a time interval, press the number of that
 interval (1 - 9) or LEFT / RIGHT until that interval is indicated in the
 upper left of the screen.

To view the motion of the elevator select the GO softkey or press ALPHA G

To toggle between the velocity time and position time graphs press the DISP
 softkey or ALPHA D

To clear the graph, press PRGM or press the CLR softkey.

If you have sent your graph, and then cleared it, you may recall it by
 pressing the RCLL softkey.

To quit, press 2nd QUIT or press the QUIT softkey.

To send the motion of your calculator to the class and to NetLogo, press the SEND softkey or ALPHA S. When the graphs are sent to the class and NetLogo, everyone can collect the results via the GET softkey or ALPHA R. To cycle among the graphs on a calculator, press ALPHA followed by LEFT or RIGHT.

THINGS TO NOTICE

Notice if an elevator moves more than 1 floor during an interval, it equally divides the amount of time spent traveling through each floor.

THINGS TO TRY

Identify your elevator (necessary even with the first use!)

Have your elevator sit at the third floor during the fourth time segment. What is the same / different between the solutions?

Make a traveling / standing wave.

Have a velocity of +2 during the fourth time interval.

Start and End at the same floor.

EXTENDING THE MODEL

A real elevator does not move at a constant speed when moving from floor to floor. It will build its speed gradually until it has reached a constant speed. Then before reaching the floor it is supposed to stop on, it will slow down. Try to make this happen as a part of the model.

CREDITS AND REFERENCES

This activity and associated models and materials was created as part of the project: PARTICIPATORY SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. The project gratefully acknowledges the support of the National Science Foundation (REPP program) -- grant number REC #9814682.

Copyright 2000 by Uri Wilensky & Walter Stroup. Updated 2001,2002. All rights reserved.

Permission to use, copy, or modify this software and its associated documentation, models and curricular materials for educational and research purposes only and without fee is hereby granted, provided that this copyright notice and the original authors' names appear on all copies and supporting documentation. For any other uses of this software, in original or modified form, including, but not limited to distribution in whole or in part, specific prior permission must be obtained from Uri Wilensky and Walter Stroup. These programs shall not be used, rewritten, or adapted as the basis of a commercial or hardware product without first obtaining appropriate licenses from Uri Wilensky & Walter Stroup. We make no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

To refer to this model in academic publications, please use: Wilensky, U. & Stroup, W. (2000). NetLogo HubNet Elevators model. <http://ccl.northwestern.edu/netlogo/models/HubNetElevators>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

In other publications, please use: Copyright 2000 by Uri Wilensky and Walter Stroup. All rights reserved. See <http://ccl.northwestern.edu/netlogo/models/HubNetElevators> for terms of use.

Equipment/Materials Needed:

- TI Navigator System
- NetLogo Software
- Delta Blocks (optional)
- Projection System/ Personal computer
- NetLogo model: Elevators.nlogo

Keywords

- Graphing
- Slope
- Velocity
- Y-intercept
- Position
- Derivative
- Signed Addition

Elevators Handouts

Regression

Subject Area

Mathematics, Science, Social Sciences

Topics

Linear Functions, Linear Regression, Mathematical Modeling, Data Analysis

Abstract/Summary

Like the function activity, this activity has students control the movement of a point in the Cartesian coordinate system. As they move their points, NetLogo computes a linear regression. The goal of the activity is for students to develop an understanding of regression and other statistical ideas from trying to create ensembles of points with certain statistical properties (coefficient of correlation = 0.7, positive slope, etc.). In a sense this is "backward" from how students usually encounter regression. Typically students start with a collection of points and compute the statistical properties. To connect with the "normal order" of generating regression analyses and to start off with real data, the first activity has students move to points that represent height and arm span. NetLogo will compute the regression. In the second activity, students will work backwards to create distributions with target statistical properties.

Prerequisites

Introduction to Cartesian coordinate system, Some Familiarity with Functions

Teacher Notes/Procedures

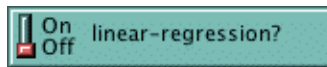
The included handouts will help structure students' involvement with these activities. Open the Regression NetLogo model found in the Models Library. Look to the Top-Level Tips for directions on how to enable the activity on the server and clear any old data. The Top-Level Tips will also show you how to change the size of the Graphics Window because the default size of the window will not work for the height and arm span data. You will also need to send out new settings to the calculators to work with this body data. Just press the Re-Run button in the NetLogo interface.

Activity One

This activity begins with the students measuring their height and their arm-span. Once they have this information, they input their data into the TI Navigator activity Function Activity. They can then individually view the class data set, and come up with an analytical function that they each think best models the phenomenon of arm-span varying with height. Through a discussion of their guesses the students can begin to develop ideas of what a "good fit" might be and this will set them up for engaging the idea of regressions. The standard approach to computing "best fit" is, obviously, a very good way of coming up with an overall function but students should also understand that it is only one of many possible ways to do this. Some alternatives may be considered better than others, and part of what you want students to consider and discuss is what makes some approaches "better" than others. For example, do you want a way of coming up with a line that is very sensitive to what might be happening at the extremes of the dataset (many students, when first confronted with drawing a best-fit line will simply connect the endpoints of a dataset)? Does it matter whether the line goes up or goes down? Or whether the data points are all positive or not? Why or why not?

Once everybody has logged in, you as the teacher will need to determine the screen settings that everyone will use. To accommodate heights and arm spans, you might need to adjust the size of the NetLogo Graphics Window. See the Top-Level Tips to find out how to do this. The adjusted settings will be sent to the server for the calculators to use as they go into the PICK PNTS screen.

Turn the LINEAR-REGRESSION? switch to OFF.



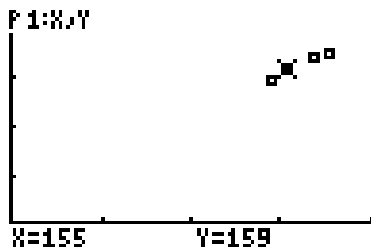
You want students to first create their own best-fit lines.

Now that everyone has the same settings, the students need to submit their data point. Select the PICK PNTS option from the main menu. Everybody will see a crosshair indicating their location, along with indicators at the top of the screen showing the X and Y values of the point and the step size.



Move the crosshairs using the arrow buttons. Use the STEP softkey to change the step-size to 5 - otherwise, it could take a while to find the point showing the height and arm-span. Once the data point has been found, select the DONE softkey. This will send the data point to the server for the class to use and also return the program to the main menu.

To view the class data set, select the VIEW PNTS option. The class data set will be displayed, and the calculator will be in Trace mode.

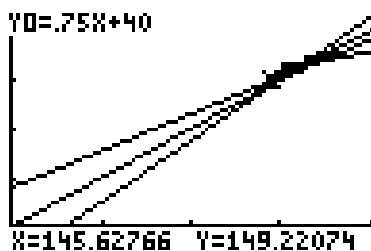


Trace mode allows you to move between the points using the arrow buttons. Ask students what it means for one number to be larger than the other. By jumping from point to point does it seem that arm span is generally greater or less than height? To exit Trace mode and bring up a set of menu options, press the ENTER button. As more members of the class submit their data point, you can update the information using the RFSH softkey. Once you have the data, you can select DONE to return to the main menu in order to fit a function to the data.

Choose option CREATE EQN to try to generate a function that models the data. You will be prompted to enter an equation - enter one that you think will best fit the data. The graph of this function will be displayed, and you can again Trace around. When you hit enter, menu options will display. REDO allows you to try a different function. When each student is satisfied that he or she has found a best function for the data set, they should select DONE. This will send their function to the class, and return them to the Main Menu.

NOTE: There is no "error trapping" in this program (unlike if you were using the Function capabilities of the calculator alone). Students must enter expressions that can be interpreted. The #1 most common error is confusing the role of the negative key with the minus key. Minus is an operation; negative is a property of a number. Confusing the two will cause the program to "crash out." The student will then have to re-login after first clearing the memory of the calculator.

Now, by choosing VIEW EQNS you can see the functions submitted by the class.



You can trace through the functions (using the up and down arrows) and all the data now (using the left and right arrows). The analytical expressions for the functions are displayed in the upper left corner of the screen. When you press ENTER, menu options appear. NEXT allows you to cycle through the class set of equations and will wrap around to the beginning when you go past the last functions. RFSH allows you to get updated functions as students submit them.

Discuss with the students and encourage them to really explore which one line (or lines) they think is (are) the best fit. Students may use a variety of criteria, ranging from "it looks good" to "it seems to be pretty close to all the points" to "I chose USE CALC and ran a regression" (which a student may already know how to use). Have students try to state their strategy for determining a function. Compare the students' strategies, and rationales for different functions.

This discussion will set the stage for the second activity, where the class will learn about regressions and will begin to explore some of the properties of regressions. To finish this first activity and lead into the next, you may want to demonstrate running a linear regression on the data. At the Main Menu, choose option USE CALC and do the following to produce a regression.

In NetLogo, you may (or may not) want to switch the LINEAR-REGRESSION? switch to ON.

Activity Two

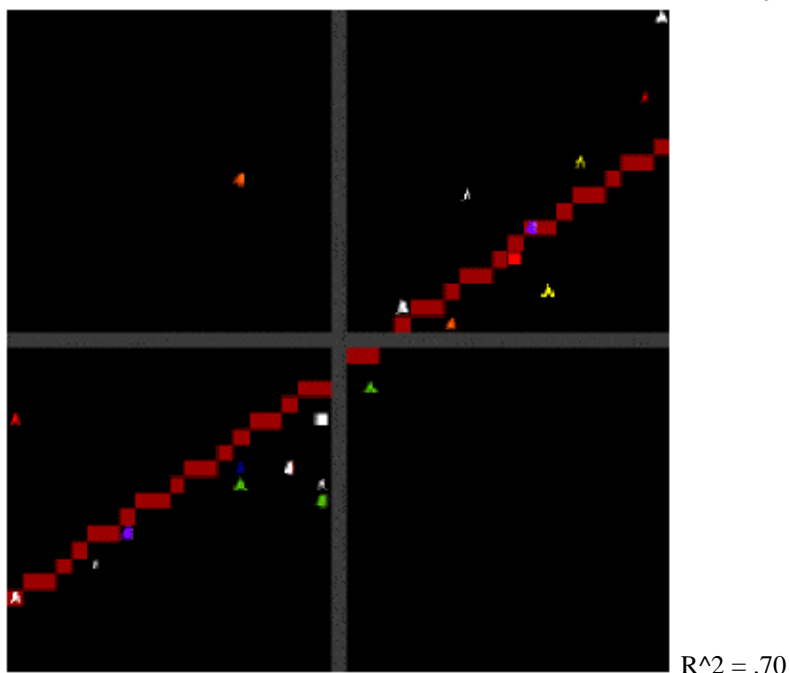
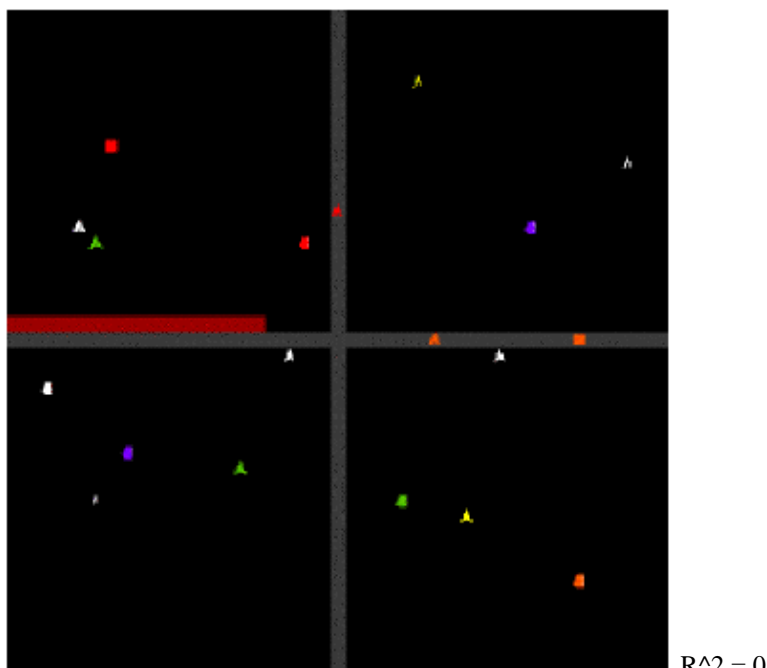
In this activity, the students create a mock data set, and by altering it, they can explore the properties of a linear regression. You need to make sure that you have the NetLogo model Regression.nlogo running.

First, you will need to change the settings for the calculator by editing the NetLogo Graphics Window so that screen-edge-x has a value of 23 and screen-edge-y has a value of 15. Now press the Re-Run button.

Once the settings have been sent to the server, the calculators will retrieve them when students go into the PICK PNTS screen.

In the NetLogo model, press the Go button. As you and the students select option PICK PNTS in the calculator activity, your points will appear in the NetLogo model. Take a moment for everyone to get used to the interface. Once three people have appeared as mock data points, a red line will draw across the NetLogo screen. This line is the result of a linear regression analysis of the mock data set.

Give the class some time to move around and acquaint themselves with the interface. Once everyone seems to have found themselves in the simulation and is comfortable moving around, challenge them to make the R^2 number at the side get to around .70. (Resist the urge to tell them what this number represents!) Give them plenty of time to try different things as a class, and let them discuss their ideas about what R^2 might represent.



As they suggest different possibilities, ask them "How would you check that?" Have students take turns giving everyone else directions (like "move to the left" or "move together" or "make your Y equal to your X") as they try to figure out what R^2 means.

Remember - this process of exploration may take a while. However, once the class starts to seem to be getting the idea, challenge them to reach other R^2 values. How about .9? Or .2? Can they make R^2 be equal to 1? Or 0?

Once they have reached any one of these values, ask them if they can find lines with the same value or R^2 but with a negative slope.

OR, once they've reached a target value, ask the students if/how this value will change if they all take ONE step up? To the Right? Etc.

We have also seen very good conversations about whether moving a point that is "far away" from the line one step closer will have a bigger effect on the value of R^2 than moving a point "close in" one step closer. Ask an individual to move one step, observe the change, and then move back. Try this with several different students. Try to understand how what you observe works for near and far points in different regions of the ensemble.

Make sure students are pushed to say what they think R^2 measures and whether the behaviors they've just explored are consistent with this understanding.

At some point you might want to look at the formula for computing the linear regression and/or R^2 to see if connections can be made between how the values are computed and how the regression line behaves (e.g., if everyone steps up one step, R^2 doesn't change).

Time Considerations

This activity should take one or two 60-minute class periods to complete and may be repeated several times as needed or in different curricular contexts.

Curriculum Standards

Grades 6 - 8

Make conjectures about possible relationships between two characteristics of a sample on the basis of scatter-plots of the data and approximate lines of fit; use conjectures to formulate new questions and plan new studies to answer them; explore relationships between symbolic expressions and graphs of lines, paying particular attention to the meaning of intercept and slope; model and solve contextualized problems using various representations, such as graphs, tables, and equations; use graphs to analyze the nature of changes in quantities in linear relationships.

Grades 9 - 12

Understand scatter-plots and use them to display data; for bivariate measurement data, be able to display a scatter-plot, describe its shape, and determine regression coefficients, regression equations, and correlation coefficients using technological tools; identify trends in bivariate data and find functions that model the data or transform the data so that they can be modeled; analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior; approximate and interpret rates of change from graphical and numerical data.

Curriculum Objectives

Students will analyze a data set through a scatter plot. Students will estimate the best fitting line for a scatter plot. Students will understand the basic concepts of regression as a means for analyzing a bivariate data set and learn a method for extrapolation and prediction.

Support Resources in NetLogo

These are resources that are included in the HubNet Regression model.

QuickStart Instructions

- Teacher: Follow these directions to setup the HubNet activity.
- Optional- Zoom In (see Tools in the Menu Bar) - optional
- Press the GO button.
- Everyone: Reset the RAM on your calculator (2nd MEM 7 1 2).
- Login to the calculator.
- Choose the PICK POINTS option.
- Remember your shape and color and press ENTER.
- Move around using the arrow keys to... acquaint yourselves with the interface.
- Teacher: Issue your students a challenge, such as... create a mock data set with an R^2 of .75.
- Optional- Press the NetLogo SET CHALLENGE button and enter... the challenge to be displayed in the CURRENT CHALLENGE monitor.
- Teacher: To rerun the activity, do not clear the server.
- Stop the simulation by pressing the NetLogo GO button.
- Press the NetLogo RE-RUN button.
- Press the GO button.
- Everyone: Exit to the calculator Main Menu.
- Choose the RESTART option from the calculator Main Menu.
- Choose the PICK POINTS option and continue.
- Teacher: To start the simulation over with a new group,... stop the model by pressing the NetLogo GO button, if it is on.
- Have everyone, including yourself, logout of their calculators.
- Press the ERASE ALL DATA button on the TISCHOOL site.
- Press the NetLogo SETUP button.
- Follow these instructions from the beginning again.

Information Tab

WHAT IS IT?

This model is used for an introductory approach to regressions. Linear Regression is the fitting of a straight line through a given set of points. Most commonly, the best-fit line is used. The best-fit line is the line that has the highest R^2 value for this set of points. R^2 is known as the correlation coefficient. This value indicates how well the line of regression fits the data on a scale from 0 to 1. The closer R^2 is to 1, the closer the line fits the data.

In this model however, you will create a set of points to create a line of regression that will have a specific R^2 value. Issue your students a challenge, such as create a mock data set with an R^2 of .5 and then of .8. How did the data change? Try to data sets that have different slopes or y-intercepts.

This activity requires the TI Navigator activity AAA - Function Activity 2.4

For further documentation, see the Participatory Simulations Guide found at <http://ccl.northwestern.edu/ps/>

HOW TO USE IT

QUICKSTART INSTRUCTIONS:

Contains instructions as to how to quickly setup the model, calculators, and TISchool web page so as to run this activity. The instructions can be found below:

Teacher: Open the TISchool site in your web browser.

Enable activity AAA - Function Activity 2.4.
Open the teacher console and press the ERASE ALL DATA button.

If it is not open already, open the NetLogo model.
If you are prompted by a Login dialog, enter your teacher id and password and any other necessary information.
Optional- Zoom In (see Tools in the Menu Bar)
Press the GO button.

Everyone: Reset the RAM on the calculator by pressing the following keys:
2nd MEM 7 1 2.
Login to the calculator.
Choose the PICK POINTS option.
Remember your shape and color and press ENTER.
Move around using the arrow keys to acquaint yourselves with the interface.

Teacher: Issue your students a challenge, such as create a mock data set with an R^2 of .75.
Optional- Press the NetLogo SET CHALLENGE button and enter the challenge to be displayed in the CURRENT CHALLENGE monitor.

Teacher: To rerun the activity, do not clear the server.
Stop the simulation by pressing the NetLogo GO button.
Press the NetLogo RE-RUN button.
Press the GO button.
Everyone: Exit to the calculator Main Menu.
Choose the RESTART option from the calculator Main Menu.
Choose the PICK POINTS option and continue.

Teacher: To start the simulation over with a new group, stop the model by pressing the NetLogo GO button, if it is on.
Have everyone, including yourself, logout of their calculators.
Press the ERASE ALL DATA button on the TISCHOOL site.
Press the NetLogo SETUP button.
Follow these instructions from the beginning again.

BUTTONS:

SETUP - clears all turtles and patches. This should only be pressed when starting out with a new group of users since all data is lost.
RE-RUN - sets up the model to be able to run again with the same users
GO - runs the simulation
SET RULE - displays an input dialog that allows the leader to enter the verbal challenge. The entered challenge is then displayed in the CURRENT CHALLENGE monitor. This is meant for a convenience of the users and has no effect on the actual running of the simulation.
NEXT >>> - shows the next quick start instruction
<<< PREVIOUS - shows the previous quick start instruction
RESET INSTRUCTIONS - shows the first quick start instruction

MONITORS:

MOUSE X - shows the pxcor of the patch the mouse is currently on, or if the mouse is no longer over the graphics window, it displays the pxcor of the patch the mouse was last on
MOUSE Y - shows the pycor of the patch the mouse is currently on, or if the mouse is no longer over the graphics window, it displays the pycor of the patch the mouse was last on
NUMBER OF POINTS AT MOUSE - shows the number of turtles on the patch the mouse is currently on, or if the mouse is no longer over the graphics

window, it displays the number of turtles on the patch the mouse was last on
 EQUATION - shows the equation for the line of regression if LINEAR-
 REGRESSION? is true
 R^2 - shows the correlation coefficient for the line of regression if
 LINEAR-REGRESSION? is true
 CURRENT CHALLENGE- displays the last challenge that was entered when the SET
 CHALLENGE button was pressed. This is meant for a convenience of the users
 and has no effect on the actual running of the simulation.

SWITCHES:

LINEAR-REGRESSION? - if true, the line of regression is shown. Otherwise,
 it is not.

CALCULATOR INFORMATION

TEACHER CALCULATOR:

Students and teacher have identical calculator programs.

STUDENT CALCULATORS:

To enter the simulation, choose the PICK POINTS option. Move your point
 around by pressing the ARROW keys.

The DONE softkey returns you to the Main Menu.

The STEP softkey prompts you to change the amount of distance you move when
 you press an ARROW key. You can choose from 0.5, 1, and 5.

THINGS TO NOTICE

What is the least number of points to create an R^2 value 0.0? 1.0?

Why does it not make sense to have a regression line for only 1 data point?

Is it harder to get an R^2 value of a particular value when there are more
 or less points? Why?

What happens to the regression line and the correlation coefficient if there
 are multiple points on a single patch?

THINGS TO TRY

Challenge the students to make data sets that have correlation coefficients
 of different values.

Move all the points the same amount in a single direction. Does the
 correlation coefficient change? The equation of the line of regression?
 Why?

Find out which points have more effect on the R^2 value and the line of
 regression. What qualities do these points have that other points lack?

Set LINEAR-REGRESSION? to OFF. Challenge the students to make a data set
 with a certain R^2 value or a particular equation for the regression line.

Turn LINEAR-REGRESSION? ON. How accurate were they? What strategies did they use? Can they be improved?

EXTENDING THE MODEL

Support having multiple data sets. Perhaps each calculator could control a particular data set.

Research other types of regression and support them.

CREDITS AND REFERENCES

This activity and associated models and materials was created as part of the project: PARTICIPATORY SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. The project gratefully acknowledges the support of the National Science Foundation (REPP program) -- grant number REC #9814682.

Copyright 2000 by Uri Wilensky & Walter Stroup. Updated 2001,2002. All rights reserved.

Permission to use, copy, or modify this software and its associated documentation, models and curricular materials for educational and research purposes only and without fee is hereby granted, provided that this copyright notice and the original authors' names appear on all copies and supporting documentation. For any other uses of this software, in original or modified form, including, but not limited to distribution in whole or in part, specific prior permission must be obtained from Uri Wilensky and Walter Stroup. These programs shall not be used, rewritten, or adapted as the basis of a commercial or hardware product without first obtaining appropriate licenses from Uri Wilensky & Walter Stroup. We make no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

To refer to this model in academic publications, please use: Wilensky, U. & Stroup, W. (2000). NetLogo HubNet Regression model. <http://ccl.northwestern.edu/netlogo/models/HubNetRegression>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

In other publications, please use: Copyright 2000 by Uri Wilensky and Walter Stroup. All rights reserved. See <http://ccl.northwestern.edu/netlogo/models/HubNetRegression> for terms of use.

Equipment/Materials Needed

- TI Navigator System
- NetLogo Software
- NetLogo model: Regression.nlogo
- Personal computer
- Projection System (for teacher calculator and computer)
- TI Navigator Activity: AAA - Function Activity 2.4

Keyword

- Linear Functions
- Slope
- Regression
- Data Analysis
- Y-intercept
- Scatter Plots
- Modeling
- Correlation
- Statistics

[Regression Handouts](#)

People Molecules

Subject Area

Mathematics, Science

Topic

Kinetic Molecular Theory and Maxwell-Boltzmann Distribution

Abstract/Summary

The goal of this activity is for students to try to make sense of the notion that global patterns in the distribution of molecular speeds can come from random local interactions. These global patterns are what allow our macroscopic experiences to be relatively stable. Randomness doesn't necessarily mean "haphazard" or "no pattern," but it can result in very important forms of stability or apparent organization. In this activity students simulate the behavior of a gas by wearing Calculator Based Rangers (CBR's) and imitating molecules. They can then view a collective histogram of their speeds, compare that with their own individual speed histogram, and compare the class's simulated motion and resulting speed distribution with that of an actual gas. Starting with a discussion of the rules they used in their motion, students gain insight into how top-level or global patterns can emerge from local rules of interaction and movement. This insight and familiarity with some of the tools of analysis and display - including using histograms to represent the people molecules data - help support a deeper understanding of the Maxwell-Boltzmann distribution for gases, a subject that is part of nearly any curricular materials that discuss kinetic molecular theory.

Prerequisites

- Some understanding that gases are made of molecules
- Some understanding that gas molecules are free to move about

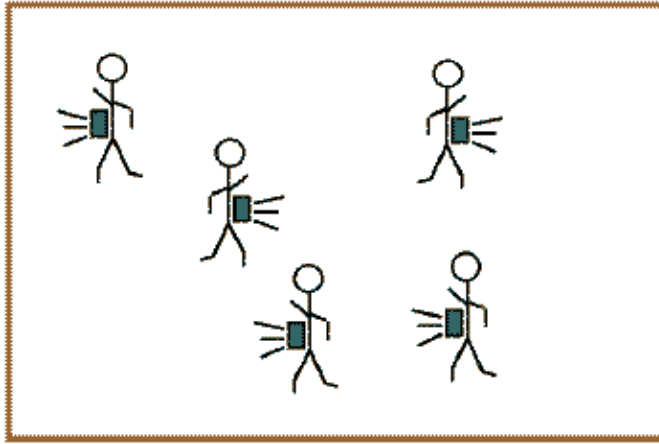
Teacher Notes/Procedures

The other activities have students interact in with the network in "real time." This activity is different in that the students first "do something" and then upload their results. This is what we call a "synchronization" mode of interaction. The activity is also different in that the students' whole bodies are part of the simulation. So while the interaction with the network is not in real time, the students' interaction with each other is, and this makes the activity very engaging.

Before the students start, explain to them that they will pretend to be molecules in a gas. Have a brief discussion in which the students discuss the rules they think they should follow, and what they think they will see. What sort of speed distribution do they expect? If they were to take "snapshots" where they could know everyone's speed at a particular moment, what would they expect to find?

Basically the core of this activity is to allow the class to collect data from and track the time-evolution of a "gas" made of people

molecules. A set of poster boards or a long roll of 3' high paper is useful for creating the "box" in which the people molecules simulate a gas.



The rest of the class can hold the paper up making walls of a box while some number of "molecules" interact. You can have teams of molecules acting out different behaviors ("move slow"; "move fast"; "start slow and speed up for 15 seconds") who "swap in" to be molecules while the current molecules become part of the wall (hold up the paper).

The CBR's (Calculator-Based Rangers from Texas Instruments) work by bouncing a sound pulse (the click you hear) off of an object and based on the time between the click and the echo, they figure out how far away the object is. The box made up of the paper is important because it provides a uniform surface for the sound pulses emitted by the CBR's to reflect off of.

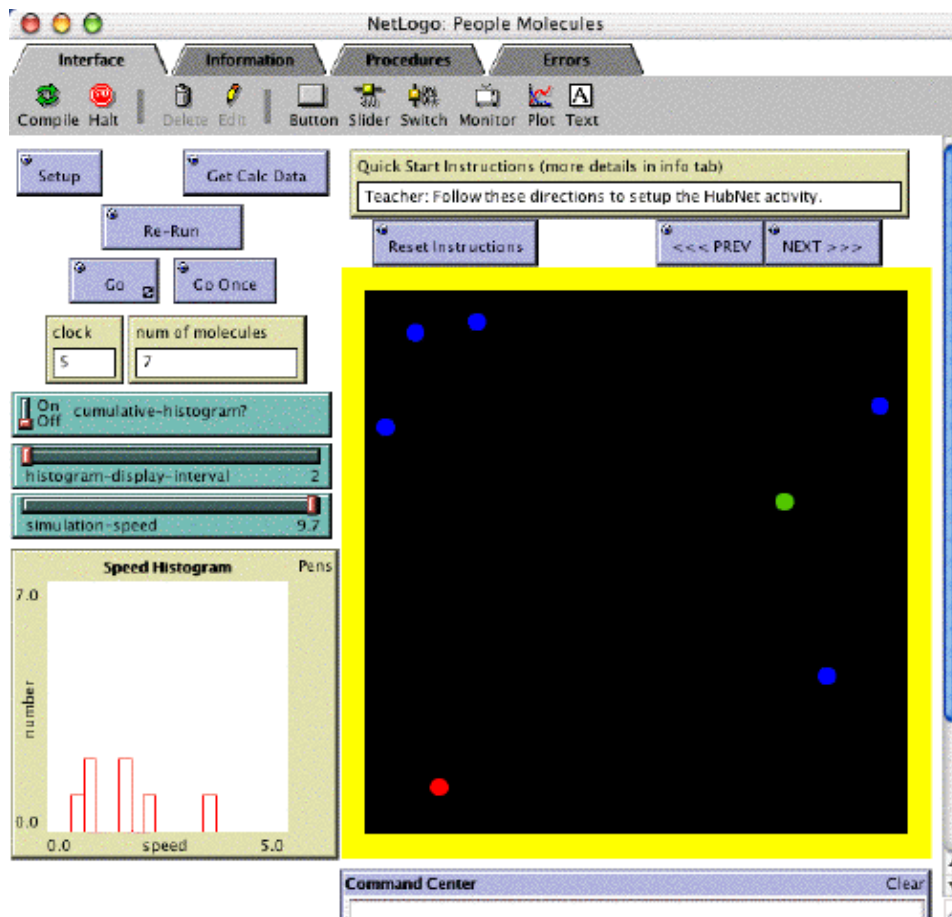
After setting up the CBR's to sample velocity (see Information tab or CRB manual) have the molecules hold the CBR to their chest, with the gold sound panel facing out horizontally. To start the simulation of a gas, they hit ENTER on their calculators and begin behaving as a gas. The motion sampling lasts about 15 seconds.

The first few times you do this, allow the students to just acquaint themselves with the simulation and the kinds of graphs that result. Later you should explore changing the system by having them "move faster" or, if you prefer, "warm up," and see if they have an intuitive sense of what this should mean for gas molecules.

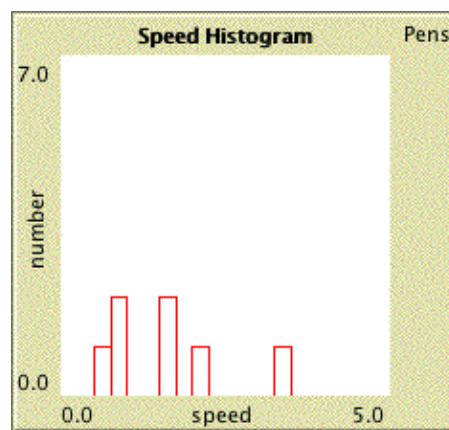
For each iteration, once the simulation is done, the students quit the Ranger program by pressing ENTER on their calculators (to exit the graph view) and then QUIT. Then, have them login to Navigator activity People Molecules. The program will automatically send a sample of their speed data to the class. On their calculator screen, the students see a histogram showing how often the CBR measured their speed to be in different ranges. They can Trace around the histogram, and press enter when they're done examining their data. This will bring up options to view their own data again, or view the class data. They can also refresh the data from the class, or quit the activity.

The students can view their individual data and the class's data on their own calculators. The class can also view the time evolution of their motion in the NetLogo model. When the students send their data, NetLogo can also access it.

To do this, press the Get Data button in the NetLogo model. NetLogo will assign the data from each "molecule" to one simulated molecule in the graphics window. Now press Go or Go Once to see the molecules move and the histogram update for this interval of time.



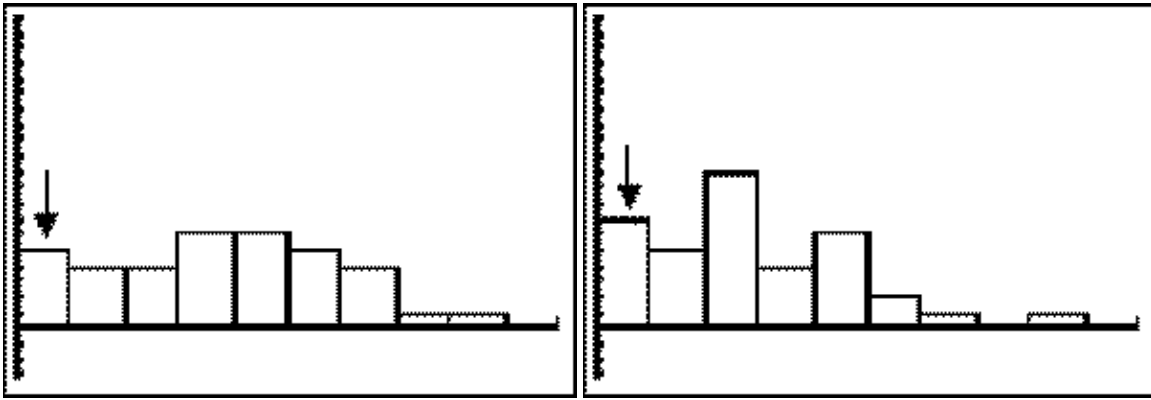
Each activation of "Go Once" (or sequentially with Go) shows the molecules moving at the simulated speeds of the students as well as the histogram of the distribution of speeds of all the molecules for that time interval. On the student calculators the histograms are for the entire 15 seconds (for either themselves or for the whole class). The NetLogo histograms are time-slices (think of something like "at every second" instead of over the whole 15 seconds).



So if students speed up during a trial this should be visible in the NetLogo histograms (the "bumps" should move to the right).

Returning to the data on the calculators, a big focus of this activity is to have students gain a better understanding of how local underlying rules can lead to top-level distributions like the Maxwell-Boltzmann distribution. People are clearly different from molecules, but this core interaction can still be explored by making sense of the rules they used as people in simulating the gas and how the global distribution reflects these local rules and constraints.

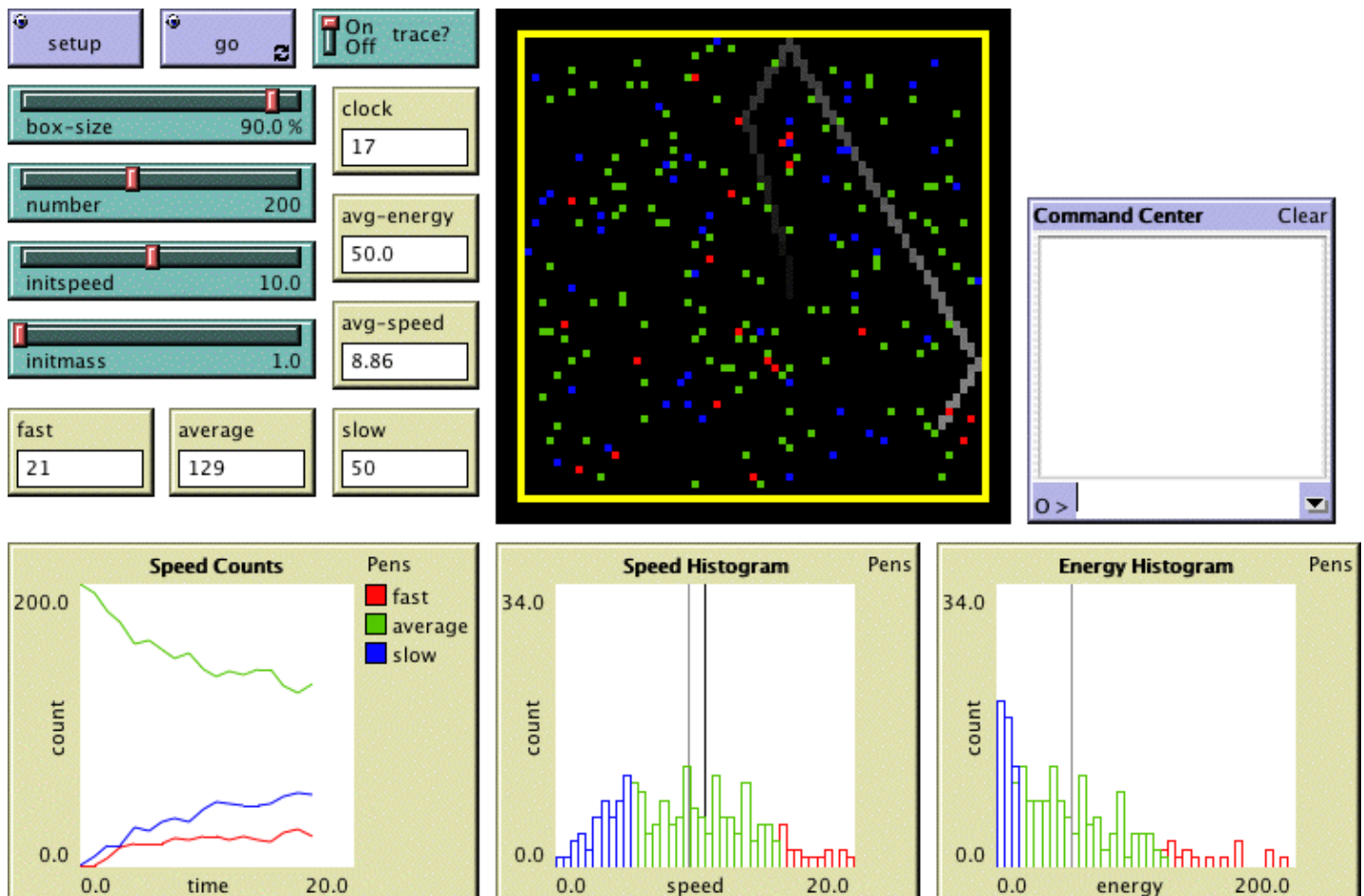
Typically, a class speed distribution will have a peak in the 0 - .5 m/s range - very slow speeds.

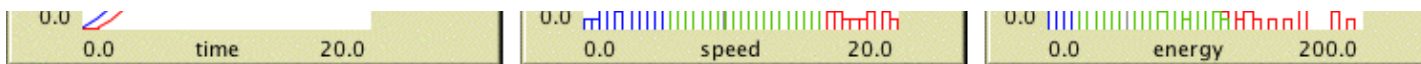


There will also tend to be a second, more rounded bump later in the distribution (at higher speeds) and then the speeds will tail off from there. Some aspects of this distribution are like the Maxwell-Boltzmann distribution and some are not. Most distinct is this "early bump." Part of what you want to explore with the class is how their local behavior might account for this bump of slower speeds. Among the ideas that students often present is this "social rule" that gas molecules are unlikely to follow: that you slow down, at least a little bit, before you collide (yes, even middle schoolers will slow down before a collision). This could have the "global" effect of creating a "slow" bump. Other accounts are also possible. You should likewise discuss why there's a large second bump and then a tailing off at higher speeds.

Let your students present their different ideas, and ask them to think through the results of their ideas. This will develop abilities for thinking about how local behaviors, even seemingly haphazard ones like moving around in a box, can have stable global patterns. If necessary, rerun the simulation, having the students pay attention to some of the factors they've mentioned.

When the students compare their speed distribution to that of an ideal gas, the Maxwell-Boltzmann distribution, they can find many similarities and differences. The two distributions have similar shapes - a hump that trails off. Where the Maxwell-Boltzmann trails off to infinity, does the student distribution follow suit? Can it? Again you can explore what crucial difference in the motions of people and of molecules leads to the peak at low speeds for the people molecules. In the same Models Library where you find the HubNet activities you'll also find models of an ideal gas.





Discussion of these observations can lead students into a deeper understanding of the rules that ideal gas molecules follow - elastic collisions like "perfect" billiard balls - lead to stable patterns like the Maxwell-Boltzmann distribution. This stability accounts for our macroscopic sense of stability in aspects of our day-to-day experience like constant pressure and relatively uniform temperature.

In your continuing exploration of statistical mechanics, you can use this activity to explore heat, simulated heat transfer, the effect on the average speed of molecules, and the related effect on the measured temperature of the gas. You can do this by asking the students to start off moving slowly but then move faster and faster as they simulate the gas. In the NetLogo model, you'll see the peak of the distribution shift to the right as the model progresses. What would have to happen for real molecules to move faster and faster? What physical phenomenon would this correspond to?

Implicit in all of this analysis is a significant introduction to the use of histograms. You can also use this activity as an introduction to histograms as a tool in data analysis. The physical action and nearly instant feedback will help the students link their actions, and the experience of their own particular motion, to important features of histograms.

Time Considerations

1 to 2 class periods

Curriculum Standards

From the NSES -

12BPS5.3 Heat consists of random motion and the vibrations of atoms, molecules, and ions. Higher temperatures cause greater atomic or molecular motion.

12BPS5.4 Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels.

Curriculum Objectives

Students develop an understanding of how conservation of energy and momentum in molecular collisions leads to the Maxwell-Boltzmann distribution. By discussing the interactions between individual molecules, and aided by their own simulation, they can understand the reasons behind the two curriculum standards listed above.

Students can explain how their own particular rules of motion lead to their own speed distribution.

Support Resources in NetLogo

These are resources that are included in the HubNet People Molecules model.

QuickStart Instructions

- Teacher: Follow these directions to setup the HubNet activity.
- First, run the physical People Molecules activity by... having your students simulate a gas by wearing CBR's set to collect... speed information. See Information for details on use of... CBR's and how to run the physical People Molecules activity.
- Then, run the Navigator activity to collect the data:
- Students: If you used a CBR in the previous activity,... login to the calculator that you used.
- A histogram of your speed will be displayed.
- When finished viewing your histogram, you can view the class'... histogram by pressing ENTER followed by the VIEW softkey.
- It may be necessary to press the RFSH button to get all the class' data.
- Compare your speed distribution with the class' distribution.
- Teacher: In the NetLogo activity, the class can view... the time evolution of the speed distribution:
- Optional- Zoom In (see Tools in the Menu Bar) - optional

- Press the GET CALC DATA button.
- When all the students' have appeared in... the NetLogo Graphics Window, press the GO button to... play the students' speeds.
- To replay the same data-set of speeds, stop the GO button by... pressing it again, if it is still depressed.
- Press the RE-RUN button, and the GO button once again.
- Teacher: To rerun the activity, do not clear the server.
- Stop the simulation by pressing the NetLogo GO button.
- Students: Collect new data with the CBR's.
- Login to each calculator used to collect data.
- Teacher: Press the GET CALC DATA button.
- When all the students' have appeared in... the NetLogo Graphics Window, press the GO button to... play the students' speeds.
- Teacher: To start the simulation over with a new group,... stop the model by pressing the NetLogo GO button, if it is on.
- Have everyone, including yourself, logout of their calculators.
- Press the ERASE ALL DATA button on the TISCHOOL site.
- Press the NetLogo SETUP button.
- Follow these instructions from the beginning again.

Information Tab

WHAT IS IT?

Students emulate gas molecules and collect speed data using CBR's. They can then aggregate this data and replay, in a limited sense, their actions. They can see how the distribution of speeds changes in time, and can use this as a jumping off point for learning about the Maxwell Boltzmann distribution.

This activity requires the TI Navigator activity AAA - People Molecules 1.1

For further documentation, see the Participatory Simulations Guide found at <http://ccl.northwestern.edu/ps/>

HOW TO USE IT

QUICKSTART INSTRUCTIONS:

Contains instructions as to how to quickly setup the model, calculators, and TISchool web page so as to run this activity. The instructions can be found below:

IMPORTANT: Follow the order described below. If the students run the Navigator activity before collecting their speed data, the Navigator program will crash.

Teacher: First, run the physical People Molecules activity by having your students simulate a gas by wearing Calculator Based Rangers (CBR's) set to collect speed information.

Divide the class into two sections, one to play the part of a gas molecule and one to hold up poster boards or large sheets of paper (at least 3 ft x 3 ft). The paper or poster boards are to reflect the sound waves emitted from the CBR. There must be enough of the people holding poster boards to be able to form a square large enough for the people holding the CBR's to move around in. Be sure to explain to each group what their role in the simulation is. Have a brief discussion where the students discuss the rules they think the people who are the gas molecules should follow, and what they think they will see. What sort of speed distribution do they expect? If they were to take "snapshots" where they could know everyone's speed at one moment, what would they expect to find?

Everyone: If you are playing the part of a molecule, reset the RAM on your calculator (2nd MEM 7 1 2). Connect a CBR to a calculator using a calculator-to-calculator or a calculator-to-CBR linking cable. Download the program to use the CBR by:

1. On the calculator, going to the LINK Menu (by pressing 2nd followed by X,T,theta,n)
 2. On the calculator, choosing the RECIEVE Menu (by pressing the RIGHT arrow key)
 3. On the calculator, pressing ENTER
 4. On the CBR, opening the flap that has the gold Sonic Sensor on it and pressing the 82/83 button
- Once the RANGER program has been received successfully, run it by pressing the PRGM key and selecting the RANGER program. prgmRANGER should appear on the Home screen of the calculator. Press ENTER. At the RANGER program's main menu, choose SETUP/SAMPLE. Change the DISPLAY to VEL and then select START NOW.

If you are holding a sheet of paper or a poster board, form a square surrounding the people using the CBR's. The square should be large enough for the people with the CBR's to be able to move freely in.

Once the square is formed around the people who are acting as gas molecules, the people who are simulating the gas molecules should hold the CBR to their chest, with the gold sound panel facing out horizontally. Then they should press ENTER on the calculators and begin simulating gas molecules.

Once the physical simulation is done, the students quit the Ranger program by hitting ENTER (to exit the graph view) and then select the QUIT option from the RANGER Main Menu. Information on general use of CBR's can be downloaded from the TI website at <http://education.ti.com/product/tech/cbr/down/download.html> and clicking on the "Getting Started with CBR" link.

Teacher: Now run the Navigator activity to collect the data:
Open the TISchool site in your web browser.
Enable activity AAA - People Molecules 1.1.
Open the teacher console and press the ERASE ALL DATA button.

Students who collected speed data with the CBR's: Login to the calculator that you used.

A histogram of your speed will be displayed. When finished viewing your histogram, you can view the class' histogram by pressing ENTER followed by the VIEW softkey. It may be necessary to press the RFSH button to get all the class' data.

Teacher: In the NetLogo activity, the class can view the time evolution of the speed distribution:

If it is not open already, open the NetLogo model.

If you are prompted by a Login dialog, enter your teacher id and password and any other necessary information.

Optional- Zoom In (see Tools in the Menu Bar)

Press the GET CALC DATA button.

When all the students' have appeared in the NetLogo Graphics Window, press the GO button to play the students' speeds.

To replay the same speeds, stop the GO button by pressing it again, if it is still depressed.

Press the RE-RUN button, and the GO button once again.

Teacher: To rerun the activity, do not clear the server.
 Stop the simulation by pressing the NetLogo GO button.
 Students: Collect new data with the CBR's.
 Login to each calculator used to collect data.
 Teacher: Press the GET CALC DATA button.
 When all the students' have appeared in the NetLogo Graphics Window, press the GO button to play the students' speeds.

To start the simulation over with a new group, stop the model by pressing the NetLogo GO button, if it is on.
 Have everyone, including yourself, logout of their calculators.
 Press the ERASE ALL DATA button on the TISCHOOL site.
 Press the NetLogo SETUP button.
 Follow these instructions from the beginning again.

BUTTONS:

 SETUP - initializes the model
 GET CALC DATA - this gets the student speed data and creates gas molecules to reenact those speeds
 GO - runs the simulation by having the gas molecules move at same speed as the students' speeds
 GO ONCE - runs the simulation by having the gas molecules move thru the next speed in the list of the students' speeds
 RE-RUN - resets the model to be able to run it again with the same data set of speeds
 NEXT >>> - shows the next quick start instruction
 <<< PREVIOUS - shows the previous quick start instruction
 RESET INSTRUCTIONS - shows the first quick start instruction

MONITORS:

 CLOCK - the number of times thru the GO procedure. Every HISTOGRAM-DISPLAY-INTERVAL the histogram SPEED HISTOGRAM will update
 NUM OF MOLECULES - displays the number of gas molecules in the Graphics Window

PLOTS:

 SPEED HISTOGRAM - histograms the speeds of all the gas molecules based on the value of CUMULATIVE-HISTOGRAM? slider

SLIDERS:

 HISTOGRAM-DISPLAY-INTERVAL - the histogram will be updated every this many number of clock ticks
 SIMULATION-SPEED - how fast the model runs

SWITCHES:

 CUMULATIVE-HISTOGRAM? - if this is true, the plot will histogram the sum of the all the speeds of the gas molecules up to this point. If false, the plot will histogram the speeds of the gas molecules for this histogram interval

CALCULATOR INFORMATION

TEACHER CALCULATOR:

 Students and teacher have identical calculator programs.

STUDENT CALCULATOR:

 The QUIT softkey prompts you to quit the calculator program. Press the YES softkey if you really want to quit, and the NO softkey if you don't.

The RFSH softkey collects any additional information from the TI server. It does nothing if there is no addition information.

The VIEW softkey toggles between the histogram of all the class's data and the histogram with just the information for this calculator.

In the histograms, you can find the values for each of the bars by pressing the RIGHT and LEFT arrow keys. Press ENTER to return to the softkey Menu.

THINGS TO NOTICE

 Where is the highest peak in the histogram? The lowest peak?

What is the general shape of the histogram?

Do the individual histograms resemble the cumulative histogram?

THINGS TO TRY

 When collecting the data in the physical People Molecules activity, challenge the class to do things like make the gas

- get warmer
- get colder
- increase the pressure of the gas
- decrease the pressure of the gas

How should these different properties affect the speed histograms? What needs to be done in order to make these properties happen?

EXTENDING THE MODEL

 Currently, the People Molecules activity only allows speed data to be collected. Modify the NetLogo model to collect data on distance traveled, and acceleration in addition to speed.

CREDITS AND REFERENCES

 This activity and associated models and materials was created as part of the project: PARTICIPATORY SIMULATIONS: NETWORK-BASED DESIGN FOR SYSTEMS LEARNING IN CLASSROOMS. The project gratefully acknowledges the support of the National Science Foundation (REPP program) -- grant number REC #9814682.

Copyright 1999 by Uri Wilensky & Walter Stroup. Updated 2001,2002. All rights reserved.

Permission to use, copy, or modify this software and its associated documentation, models and curricular materials for educational and research

purposes only and without fee is hereby granted, provided that this copyright notice and the original authors' names appear on all copies and supporting documentation. For any other uses of this software, in original or modified form, including, but not limited to distribution in whole or in part, specific prior permission must be obtained from Uri Wilensky and Walter Stroup. These programs shall not be used, rewritten, or adapted as the basis of a commercial or hardware product without first obtaining appropriate licenses from Uri Wilensky & Walter Stroup. We make no representations about the suitability of this software for any purpose. It is provided "as is" without express or implied warranty.

To refer to this model in academic publications, please use: Wilensky, U. & Stroup, W. (1999). NetLogo HubNet People Molecules model. <http://ccl.northwestern.edu/netlogo/models/HubNetPeopleMolecules>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

In other publications, please use: Copyright 1999 by Uri Wilensky and Walter Stroup. All rights reserved. See <http://ccl.northwestern.edu/netlogo/models/HubNetPeopleMolecules> for terms of use.

Equipment/Materials Needed

- TI Navigator System
- Calculator Based Rangers (at least 8 is preferable)
- Poster Boards or large paper rolls
- NetLogo model: People Molecules.nlogo
- NetLogo
- Personal computer
- Computer projection system

Keywords

- Gas
- Maxwell-Boltzmann
- Histogram
- Speed distributions
- Collision
- CBR

References

1. The Participatory Simulations project is a collaboration between Northwestern University and the University of Texas at Austin.
PI: Uri Wilensky
Co-PI: Walter Stroup
2. This activity was adapted from: Stor, M. & Briggs, W. (1998). Dice and disease in the classroom. *The Mathematics Teacher*, v. 91, no. 6. pp 464-468.
3. For more details of this approach, see Stroup, W. M. (in press). Understanding Qualitative Calculus: A Structural Synthesis of Learning Research. *International Journal of Computers for Mathematical Learning*.

Disease Data

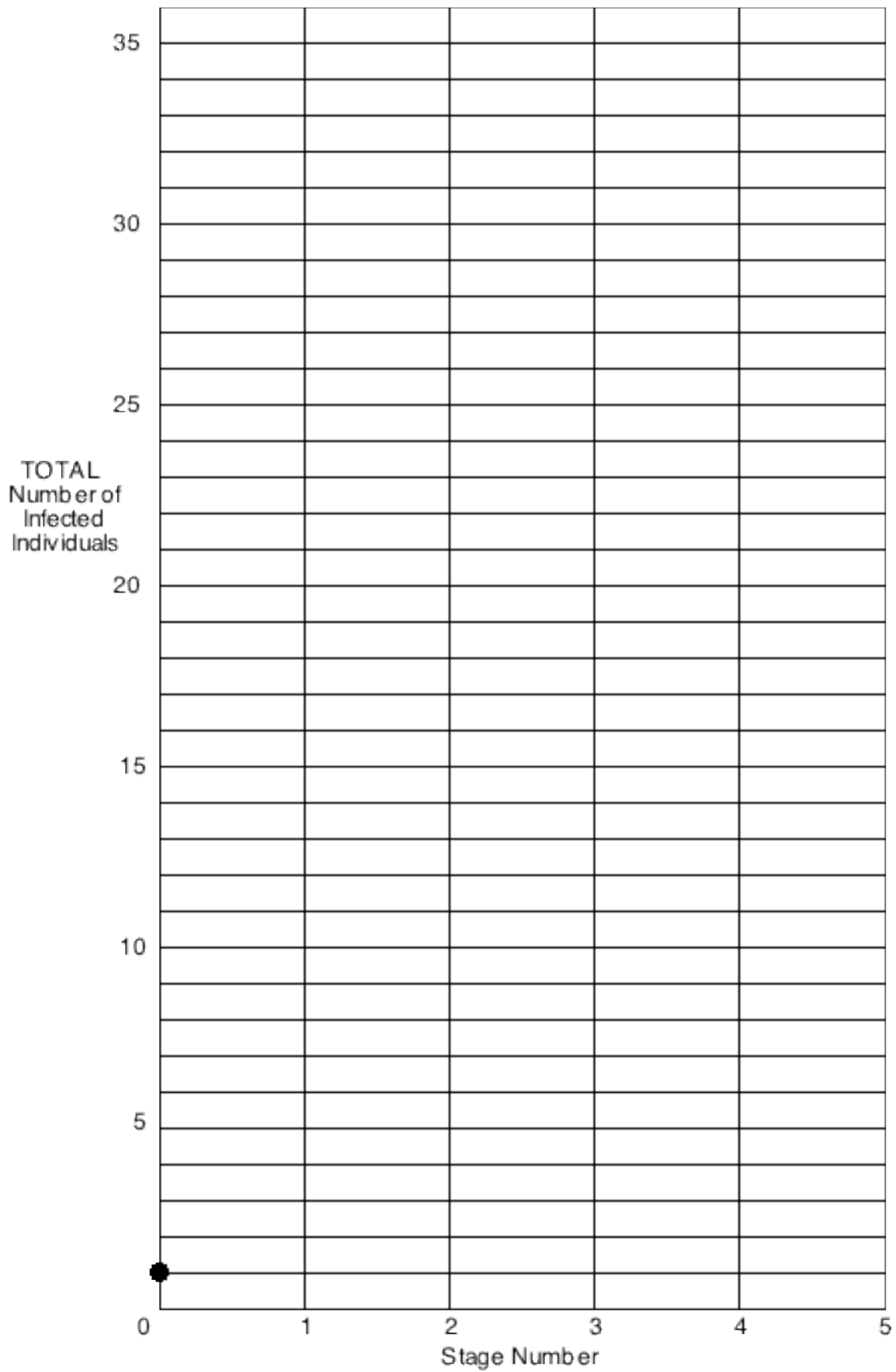
Name: _____

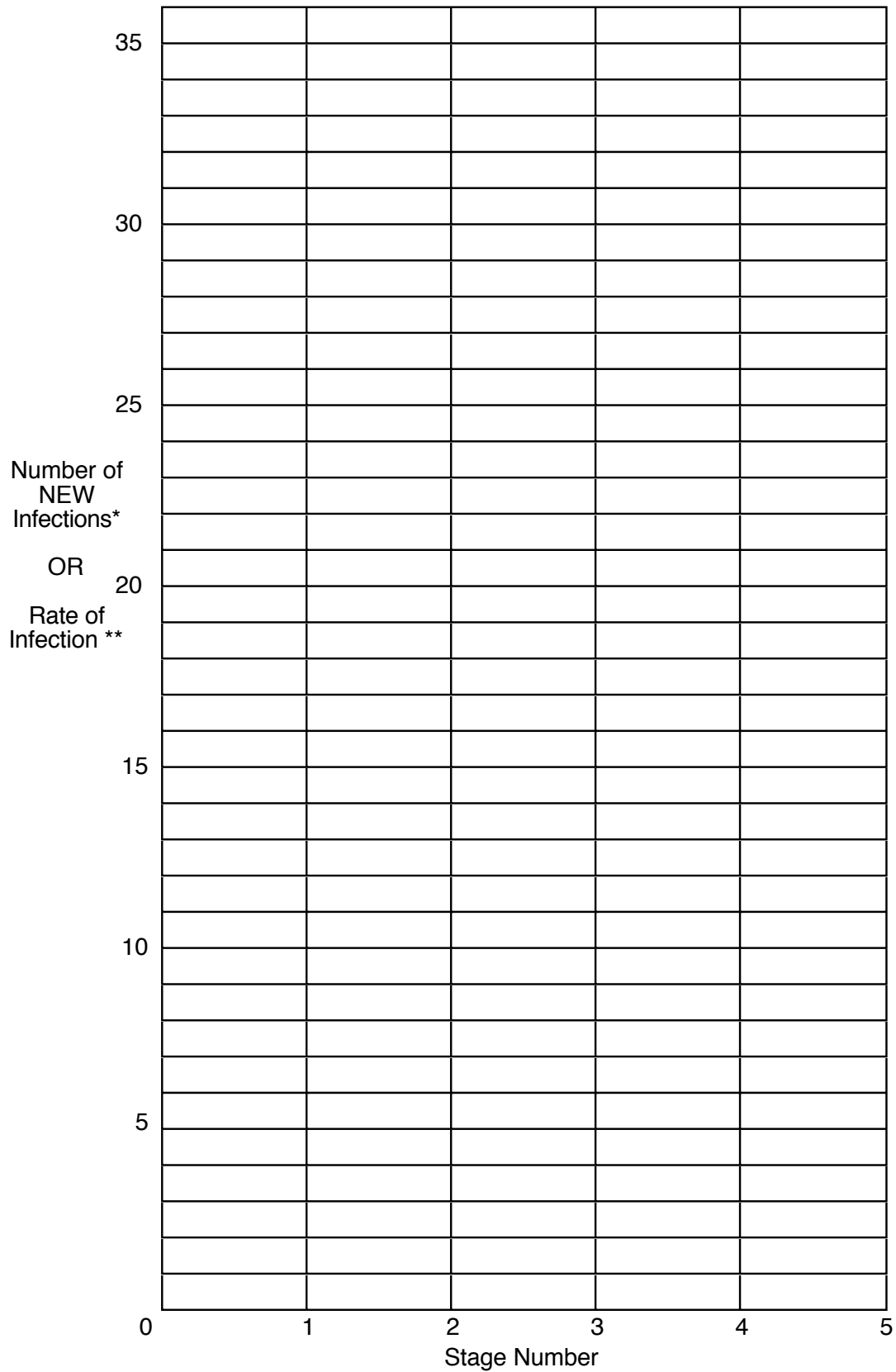
Your ID Number _____

In each stage, write down the numbers of the people you interacted with. Then write down the sum of your dice values. Each stage will be about two minutes long. After you have complete Stage 5, you will be given the high-risk sum (e.g. "5 and below"). Put a "*" next to all of your high-risk interactions. Now you will be told who was sick at Stage 0, and anyone who had a high-risk interaction with this person in Stage 1 is now sick (and so on for the other stages). As a class you will complete the second table below.

Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
ID# & Sum		ID# & Sum		ID# & Sum		ID# & Sum		ID# & Sum	

Stage Number	ID#'s of NEWLY Infected Individuals	Number of NEW Infected Individuals	TOTAL of Infected Individuals
0			
1			
2			
3			
4			
5			



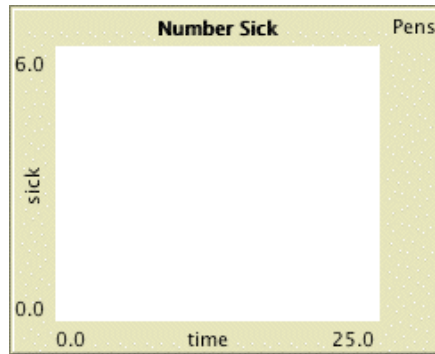


* - You should consider plotting these values in the middle of the interval OR
 ** - You should consider plotting piece-wise constant [flat] segments for the interval.

Follow-Up Worksheet

Name: _____

Sketch the total “Number Sick” graph as it appears after the simulation is

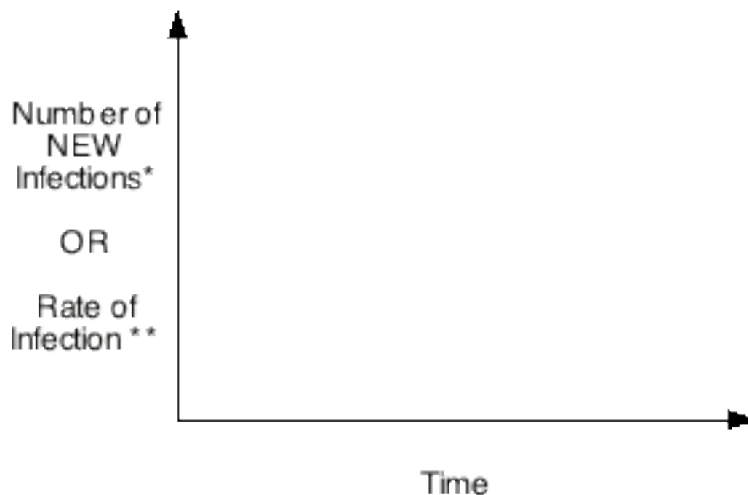


finished.

[1] What is this graph measuring?

[2] Circle on the graph where people are getting sick the fastest. Label this with the letter “A”. Circle on the graph when the disease starts to slow down its spread. Label this with the letter “B”.

[3] Try, on your own, to *sketch* what you think the other graph (the # Newly Sick or Rate of Infection Graph) would look like. This is one of the graphs from the dice and disease activity.



[4] Now re-answer the questions by placing the labels “A” and “B” on this second graph.

[5] Describe in words how the graphs would change if we changed the probability of infection? Then, using dotted lines, sketch on each of the graphs what you think would happen (how the graphs would be different).

[6] Find a graph related to market saturation. How might this graph be thought of as being like what is represented for the disease simulation?

[7] What other situations might have graphs like this?

Worksheet

Name: _____

Introduction

Each cube represents a floor that an elevator will travel. In Figure 1 below this means with six cubes the elevator will move six floors. In this activity we are going to explore what different arrangements of the cubes will mean for the motion of a computer simulated elevator. During the course of the activity a special kinds of graph will be introduced. We will try to figure out how the graphs work and what they mean for the motion of the elevator.

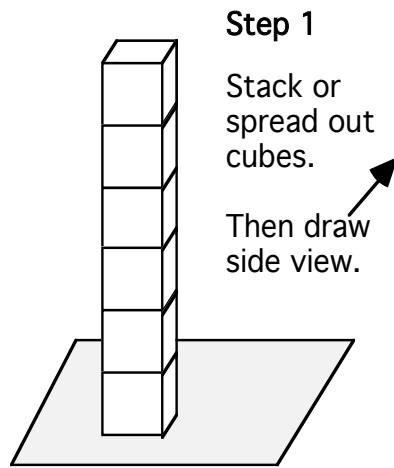


Figure 1

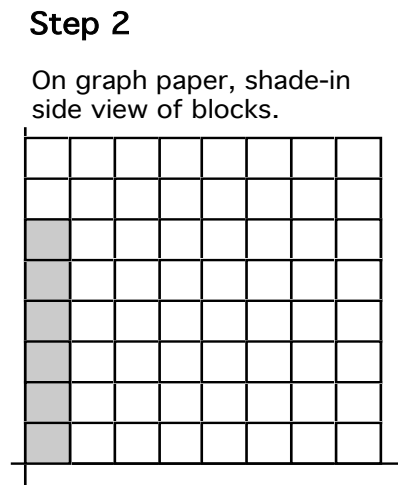


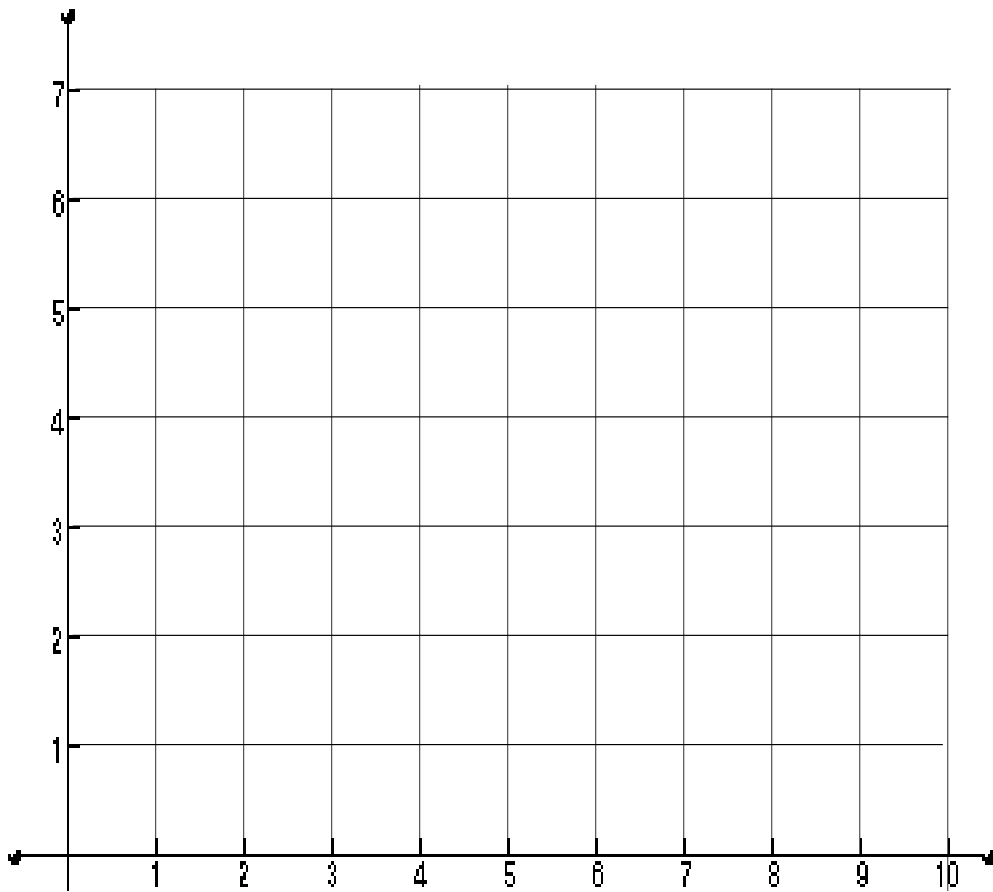
Figure 2

Getting Started

Step 1: Arrange the six cubes in any pattern you like. You may want to stack some of them (make sure they are straight on top of each other). The wall you make may have spaces in it. The wall should be only one brick thick (no bricks should be hidden behind other bricks). A very simple arrangement is shown above in Figure 1.

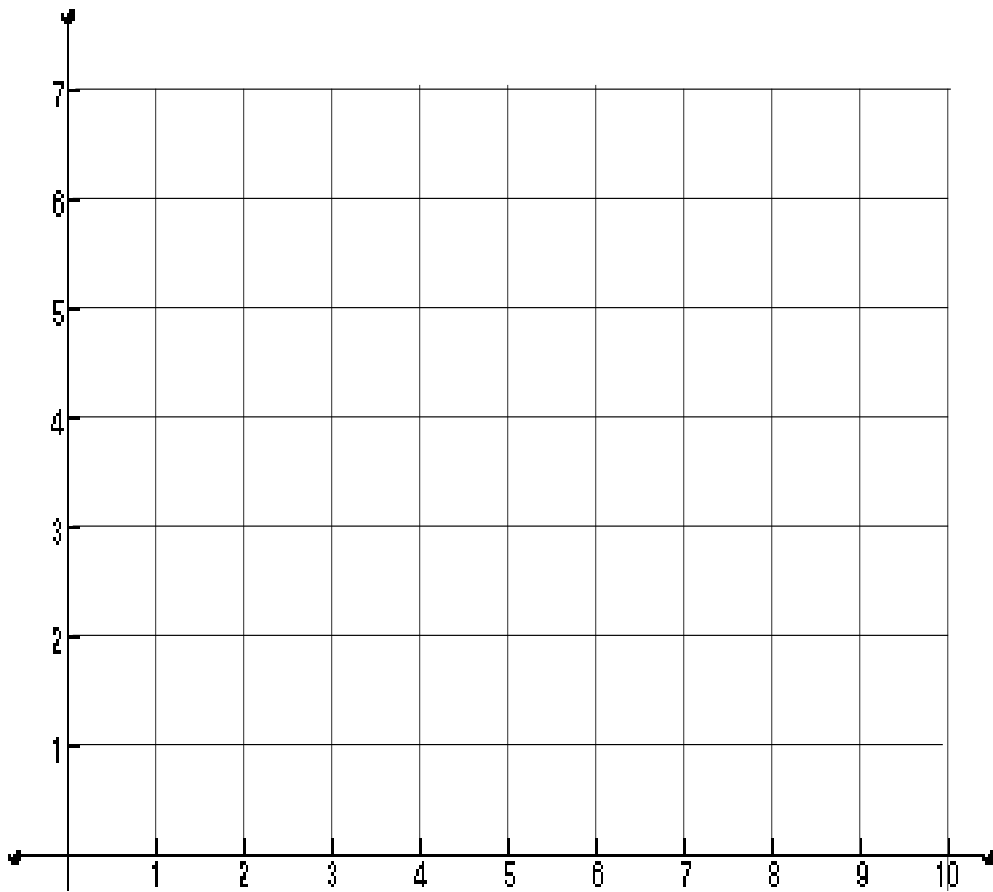
Step 2: On graph paper (given on the next two pages) shade-in the side-view of YOUR arrangement. Figure 2 above is the side view of the wall shown in Figure 1. You will not be able to answer the questions until you work with the calculator. Remember to come back to the questions later.

Your First Arrangement



- 1 What floor did the Elevator start on?
- 2 What floor did it finish on?
- 3 How did the Elevator move in each section of your graph? (you may write on your graph if you want)

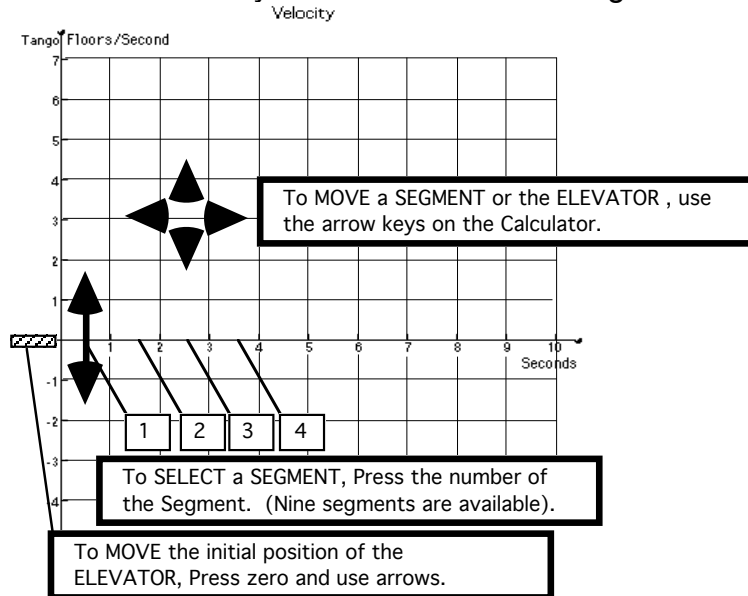
Your Second Arrangement



- 1 What floor did the Elevator start on?
- 2 What floor did it finish on?
- 3 How did the Elevator move in each section of your graph? (you may write on your graph if you want)

Introduction to Calculator Math Worlds

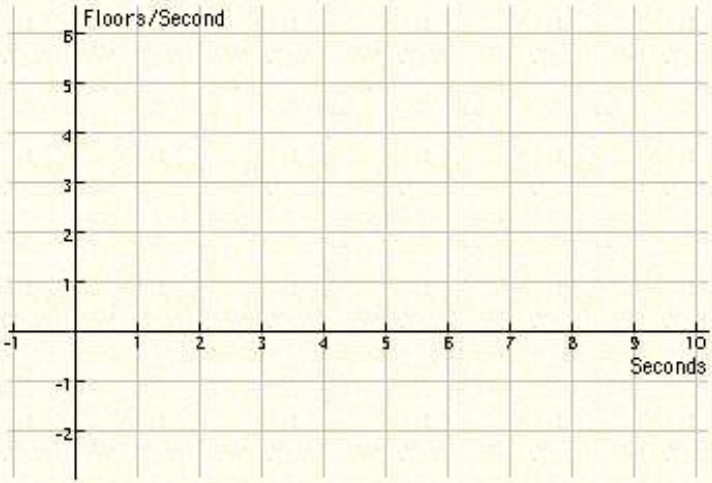
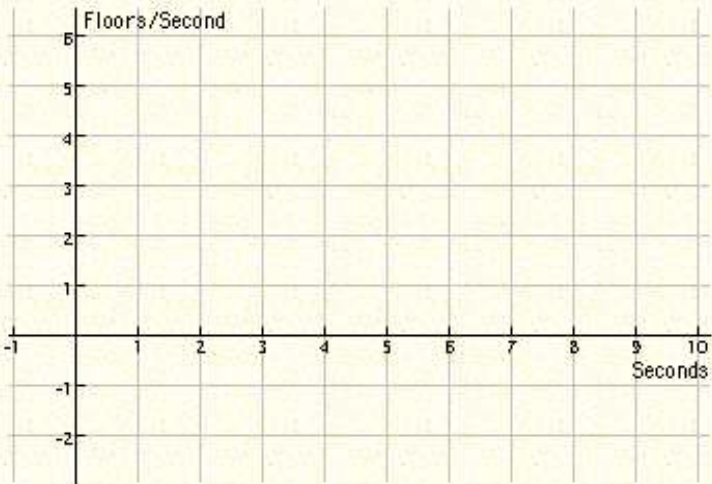
After logging on to the network you should see something like this:



- To change the initial floor for the elevator press 0 or LEFT/RIGHT arrow until 0 is indicated as the selected interval in the upper left corner of the screen.
- To change the velocity during a time interval, press the number of the interval (1-9) or LEFT/RIGHT arrows until that interval is indicated as the selected interval in the upper left corner of the screen. Then press UP/DOWN to adjust the value.
- To change the duration of a time interval, select that interval. Then press 2ND + LEFT/RIGHT to make the interval shorter/longer by half a second. Intervals default at one unit of time long (roughly a second), and can range from .5 to 3. [Note: half intervals currently will not show in the graphics window of NetLogo].
- To view the motion of the elevator, select the GO softkey.
- Press the decimal key [.] to stop a simulation.
- To toggle your display between the *velocity vs. time* graph and the *position vs. time* graph, press the DISP softkey.
- To send your motion to the class and to NetLogo, press the SEND softkey.
- To view the class' set of motions individually, press the GET softkey. The first graph sent will then appear on your screen. To cycle through all the solutions, press ALPHA + LEFT/RIGHT. Each solution can be edited on your calculator.
- To toggle between sets of softkey menu options, press the MORE softkey.
- To restore your solution, press the RCLL softkey (which is on the second menu, accessible via the MORE softkey)
- To clear your current graph, press the CLR softkey.
- To quit the activity, press the QUIT softkey. The program will ask you to verify that you would like to quit.

Opening Challenge

The elevator starts on floor zero. It needs to go to the third floor, stop and pick up passengers, and then go on to the sixth floor where it picks up more people. Create graphs for two different ways an elevator might pick these people up. Sketch the graphs and then describe the motion of the elevator (you can write the descriptions on the graph or on the side). Press SEND with your more interesting graph.

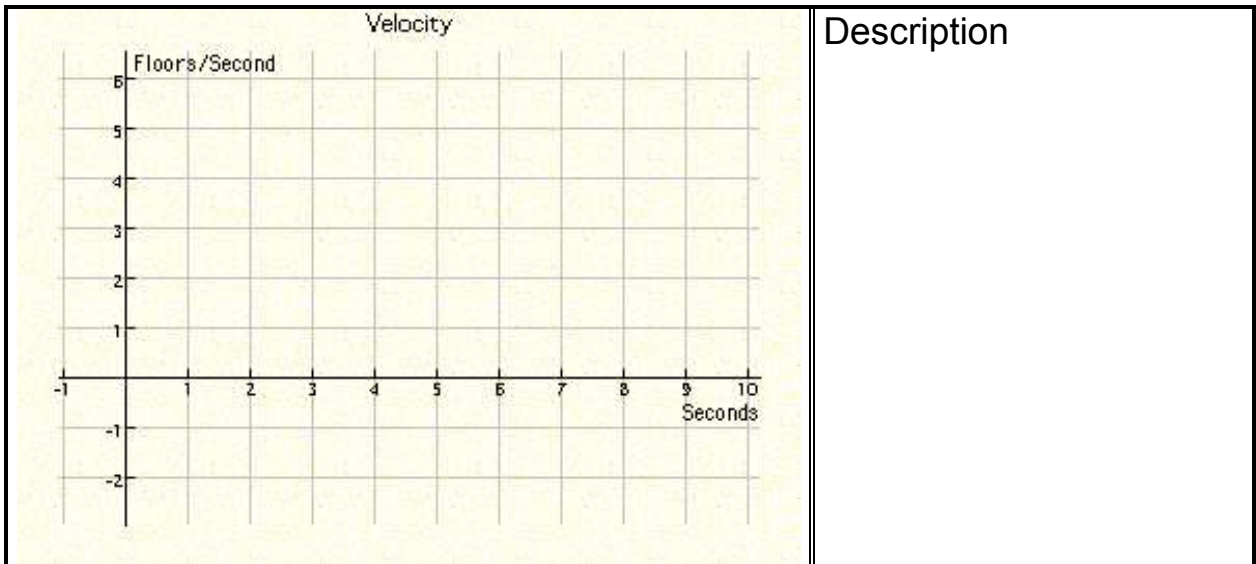
<p style="text-align: center;">Velocity</p> 	<p>Description</p>
<p style="text-align: center;">Velocity</p> 	<p>Description</p>

Make sure you run the simulations and see if your sketched motion works before you SEND it up.

Now press the DISP graph and see if you can figure out how this graph works. Press GO to see that the elevator still moves the same. This is a graph of the same motion, but it is a different kind of graph.

Second Challenge

Use 6 blocks to get the elevator to the fourth floor and stop. When you find a graph that works, press SEND.



What do you see in the upfront space? What happens?

Did anyone find a way to make the elevator go down? How did he or she do it?

General Questions

Here are some general questions regarding the motion of the simulated Elevator.

1. What does the vertical direction (up-and-down) of the graph represent?

How do you know or give an example?

2. What does the horizontal direction (side-to-side) of the graph represent?

How do you know or give an example?

3. What do blocks below the axis do?

Using one of the **velocity graph** results from the previous challenge (or an earlier challenge) keep the graphs the same but **drag the elevator** to a different starting floor.

1. How does changing the initial position of the elevator change the velocity graph (or not)?

2. Without running the simulation, what floor do you think the elevator will end up on?

Why?

Now run the simulation and compare the results to your predictions

3. What effect does changing the starting position have on the motion of the elevator?

What stays the same?

What is different?

Using one of the velocity results from the previous challenge (or an earlier challenge) keep the graphs the same but again **drag the elevator** to a different starting floor. Now we'll focus on the "other" graph.

1. Predict what the "other" (position) graph will look like.
2. Without running the simulation, what floor do you think the elevator will end up on? Now run the simulation.
3. Now switch to the position graph. What do you think changing the starting floor had on the position graph?
4. Press 0 and change the starting position of the elevator. What happens?
5. If you switched back to the velocity graph, do you think it would be the same or different? Run the simulation and check your answer?
6. Returning to the position graph, when you move the starting place of the elevator:

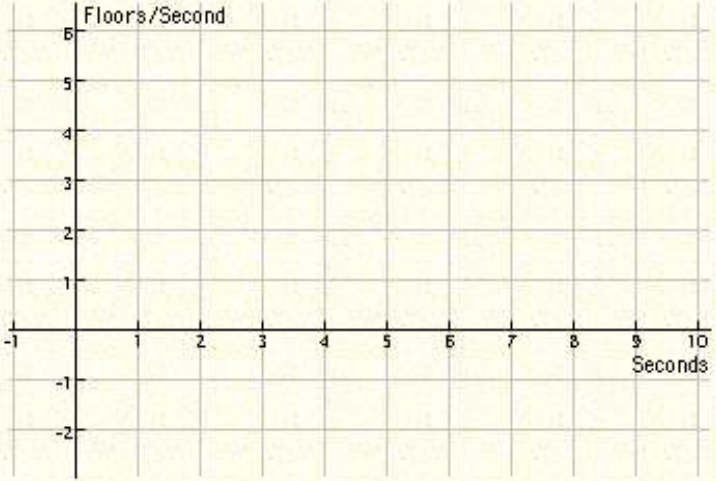
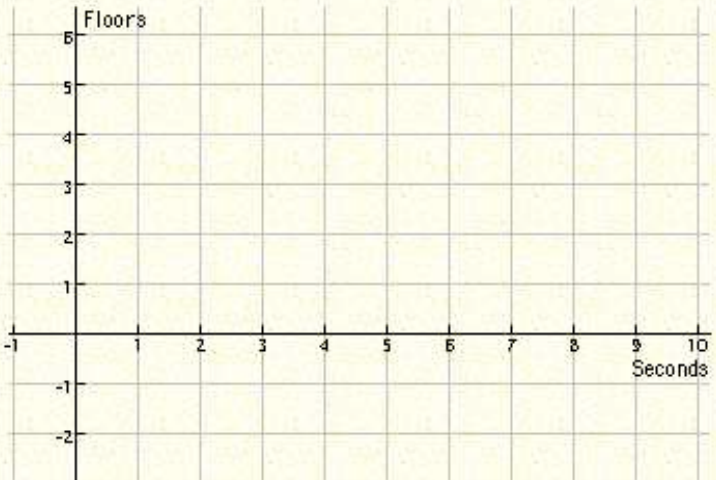
What stays the same?

What is different?

FOR THE FOLLOWING ACTIVITIES USE AS MANY BLOCKS AS YOU WANT

Challenge 3

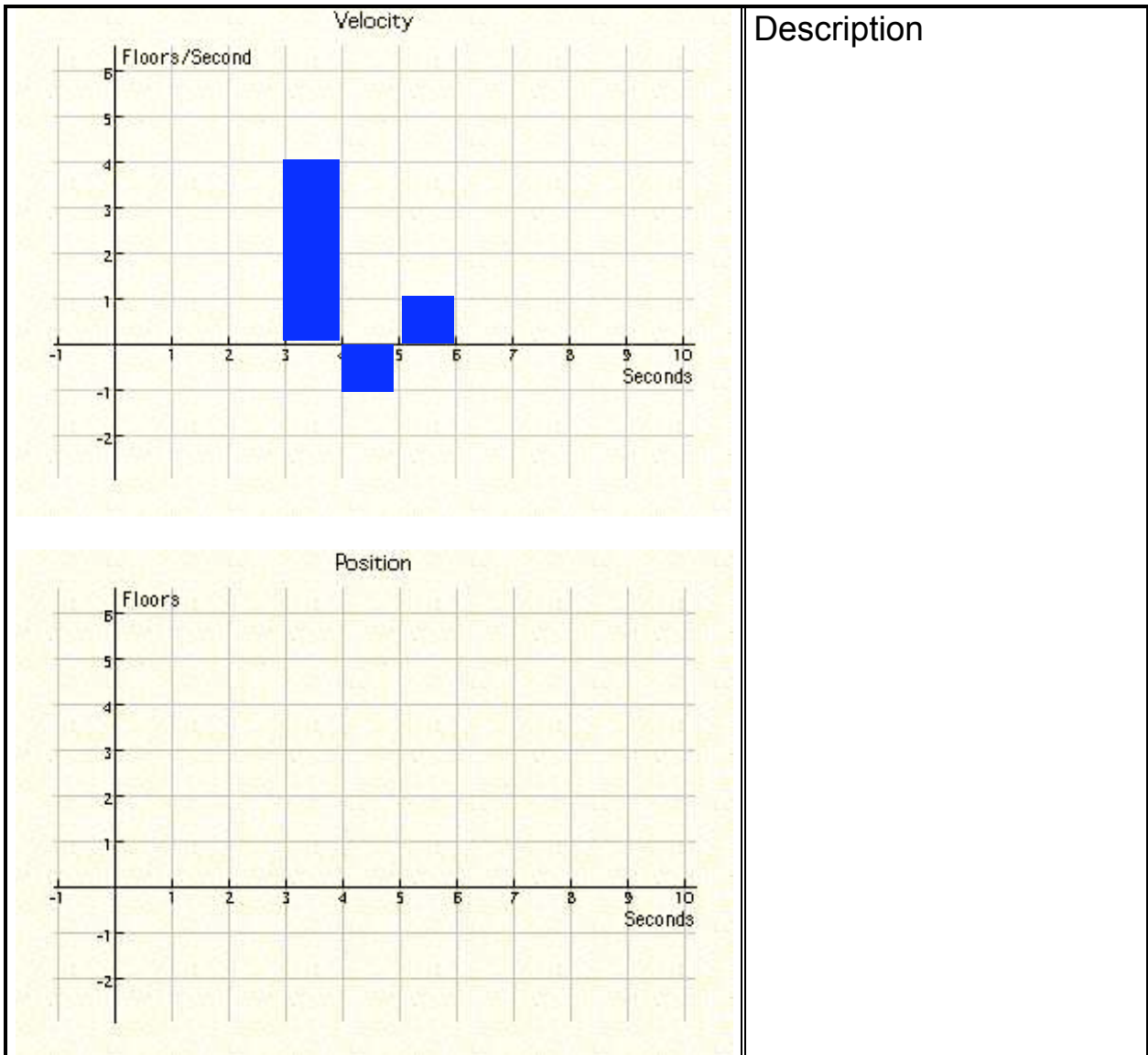
Can you find a way of having the elevator end up on the -2 floor? Sketch the graph below. Now SEND in this graph. Try and sketch the position on the second axis. Check it by pressing DISP.

Velocity	Description
	

What do you notice about all the motions and graphs together on the upfront screen?

Challenge 4

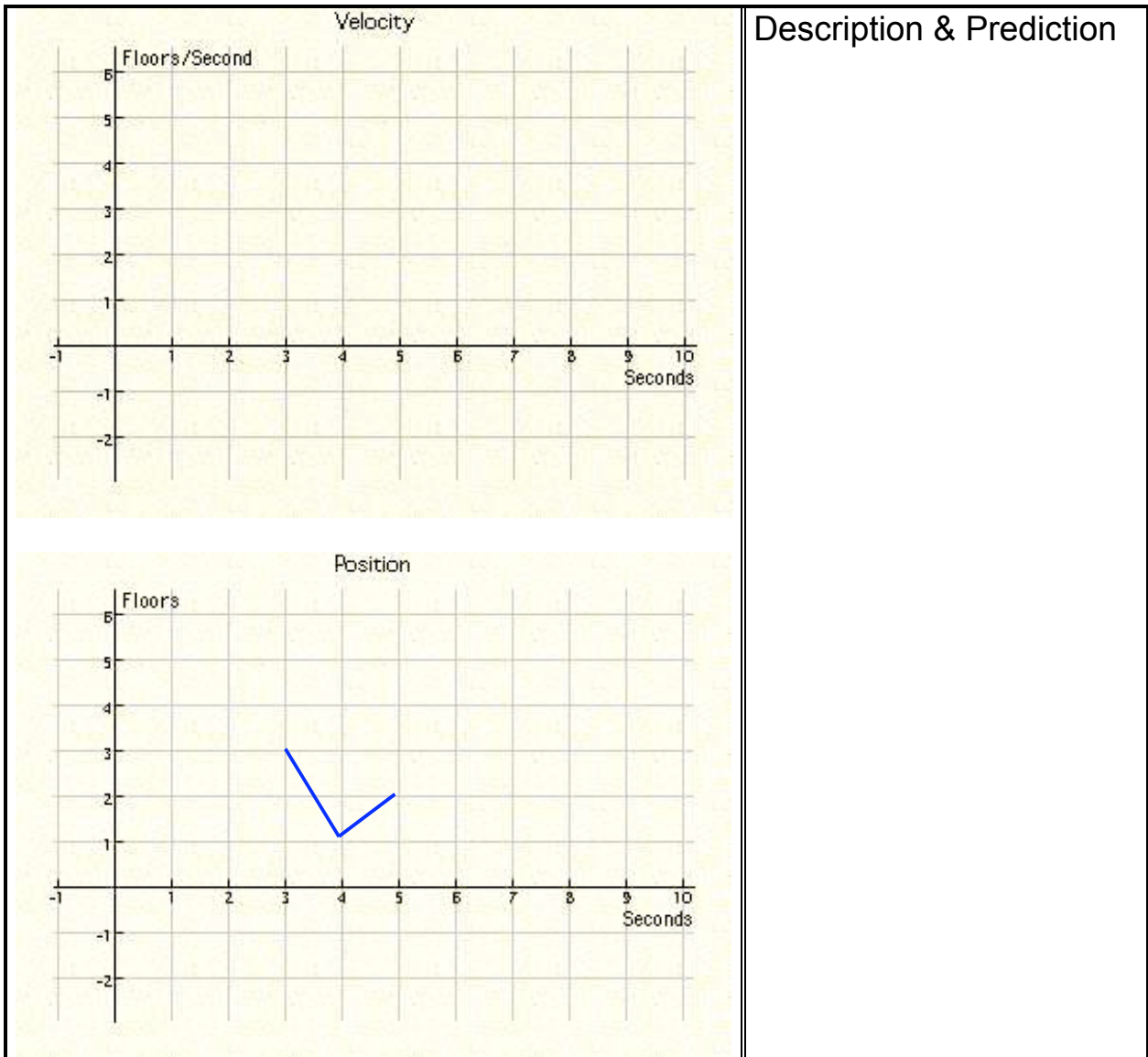
Make a complicated graph for your elevator and have it use five blocks as shown below (*it should also have blocks on either side of these five*). Describe the motion. See if you can sketch the position graph (check it with DISP). Now send your graph to the upfront space by pressing send the SEND softkey and see if you notice anything about all the graphs together.



What do you notice about the all the motions and graphs together?

Challenge 5

Create a velocity graph so that it has the segments shown as part of the position graph. Sketch both graphs. Be sure to have blocks on either side of these segments. Describe the motion and predict what you'll see upfront. What will happen during these segments?



What happens when all the motions and graphs are together?

Challenge 6

Create graphs so that the position graph goes through the point shown (and does other things on either side). Try NOT to stop at the point but have the elevator keep moving through this point. Describe the motion and predict what you'll see upfront. What will happen at this point?

Velocity	Description & Prediction
Position	

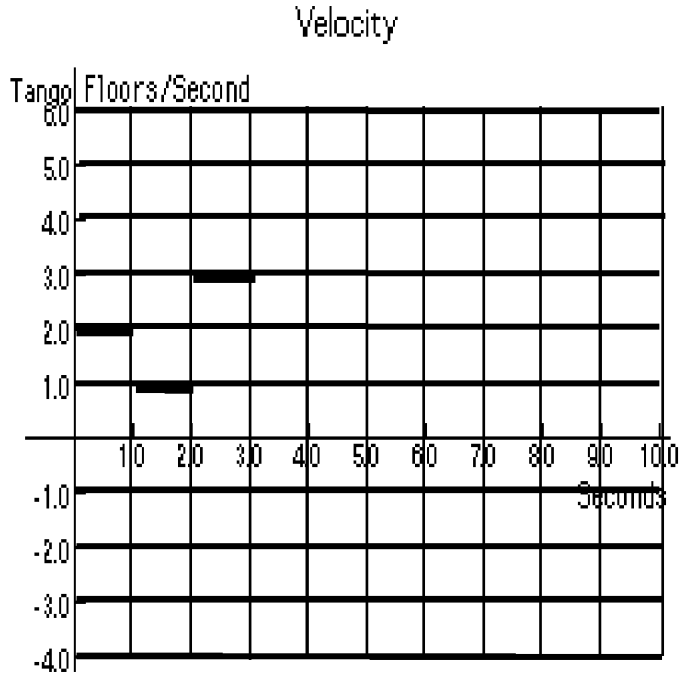
The image shows two blank coordinate grids. The top grid is titled "Velocity" and has a vertical axis labeled "Floors/Second" ranging from -2 to 6 and a horizontal axis labeled "Seconds" ranging from -1 to 10. The bottom grid is titled "Position" and has a vertical axis labeled "Floors" ranging from -2 to 6 and a horizontal axis labeled "Seconds" ranging from -1 to 10. Both grids are empty, intended for students to plot their own motion graphs.

What happens at this point when all the motions and graphs are together?

Elevator Homework 1

Name _____

[1] Answer the questions. The elevator starts at floor zero.



- a) Describe the motion of the elevator.

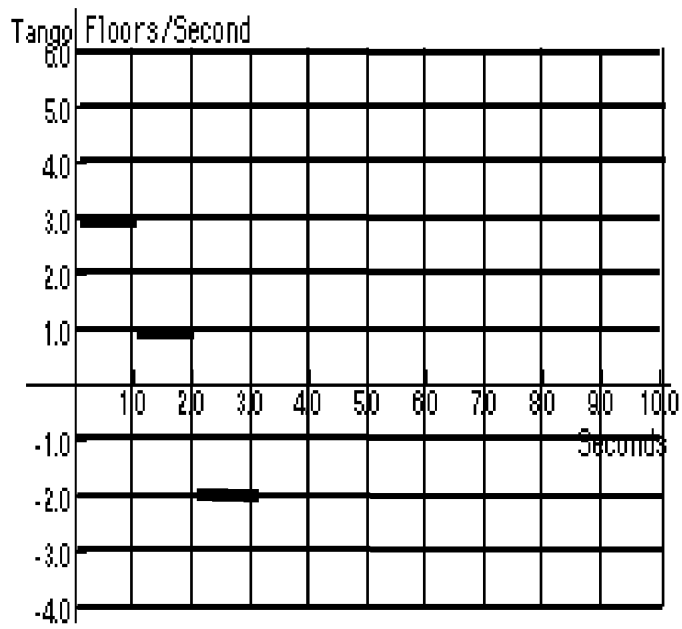
- b) Where is the elevator after 1 second?

- c) After 2 seconds?

- d) After 3 seconds?

[2] Answer the questions. The elevator starts at floor zero.

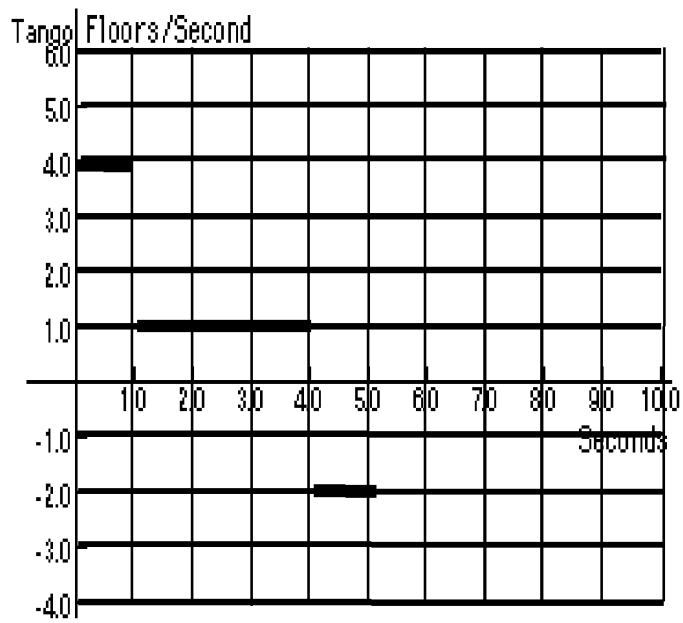
Velocity



- Describe the motion of the elevator.
- Where is the elevator after 1 second?
- After 2 seconds?
- After 3 seconds?

[3] Answer the questions. The elevator starts at floor +2.

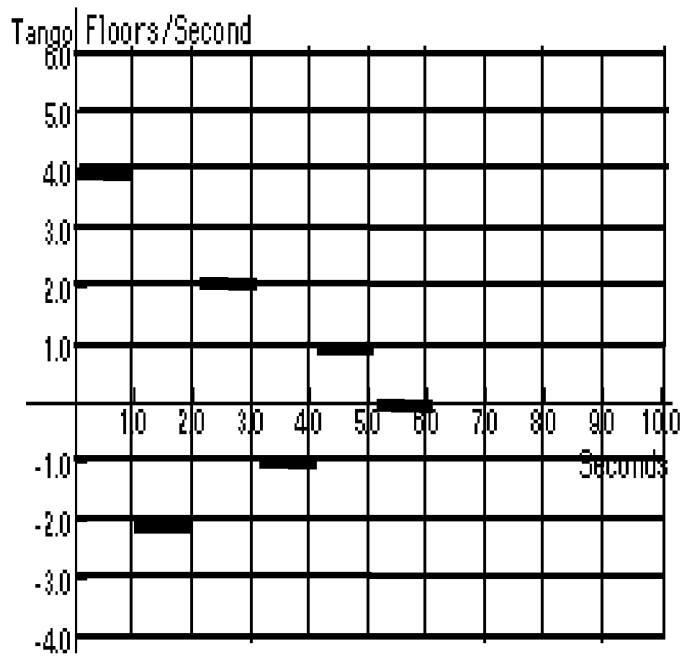
Velocity



- Describe the motion of the elevator.
- Where is the elevator after 1 second?
- After 3 seconds?
- After 5 seconds?

[4] Answer the questions. The elevator starts at floor -2

Velocity



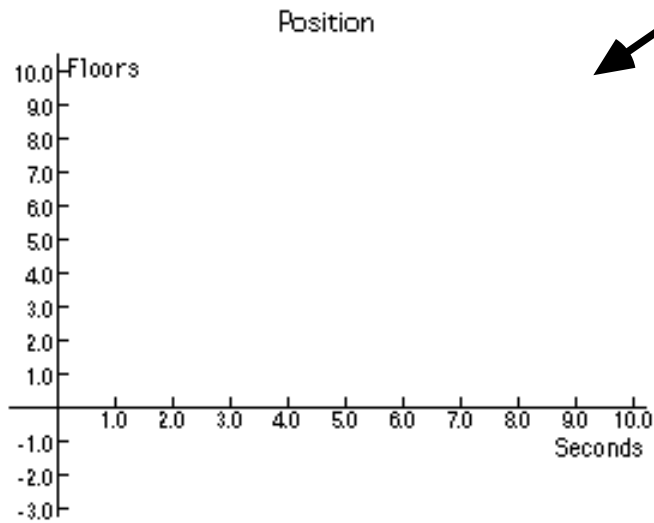
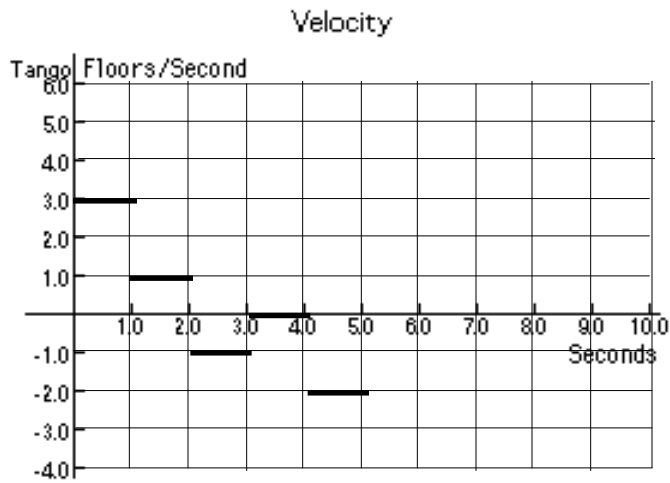
- Describe the motion of the elevator.
- Where is the elevator after 1 second?
- After 3 seconds?
- After 6 seconds?

Advanced Elevator Homework 2

Name: _____

[1] The elevator starts and floor zero and has the following velocity graph.

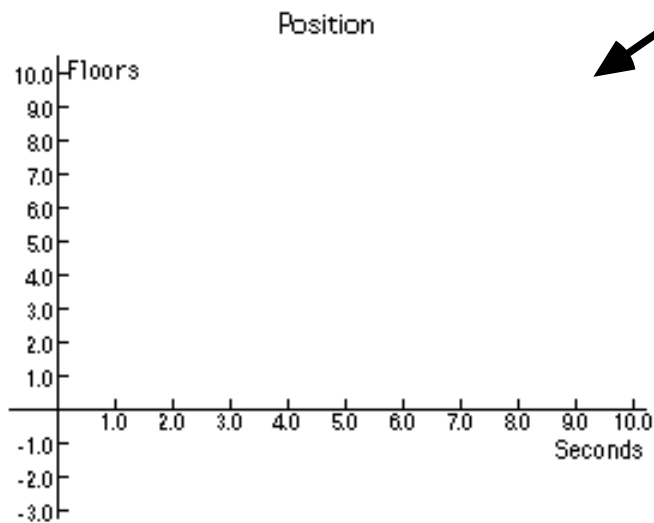
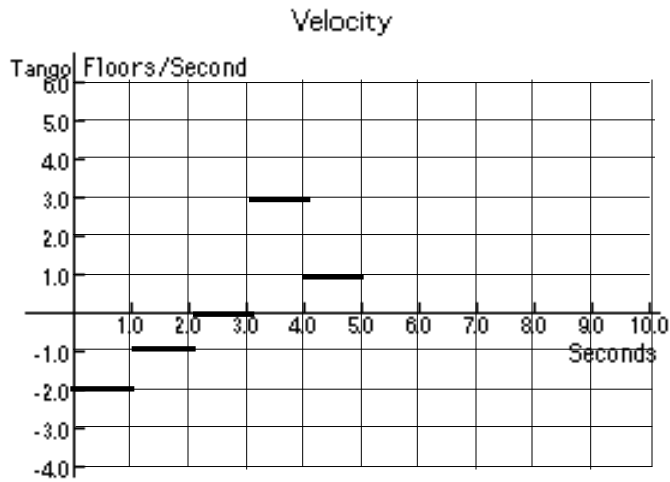
a. Draw the corresponding Position Graph for the Given Velocity graph.



- b. Where on the position graph is the elevator highest?
(circle the point)
- c. Where on the position graph is the elevator moving the fastest up?
(circle the region)
- d. Where on the position graph is the elevator moving the slowest up?
(circle the region)
- e. Where on the position graph is the elevator moving the fastest down?
(circle)

[2] The elevator starts on floor **TWO** and has the following velocity graph.

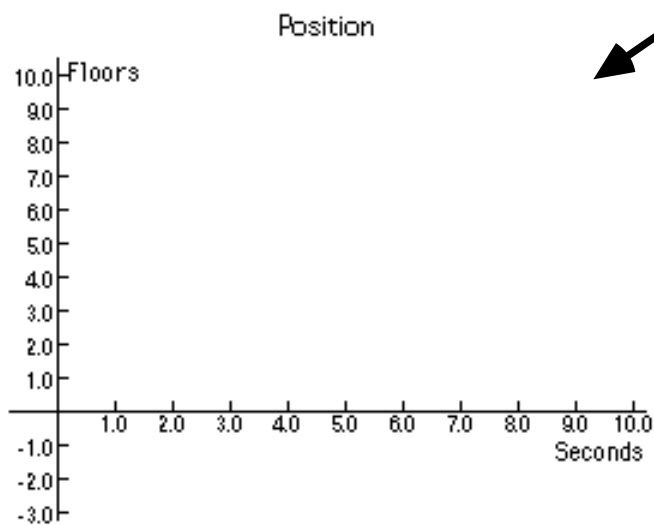
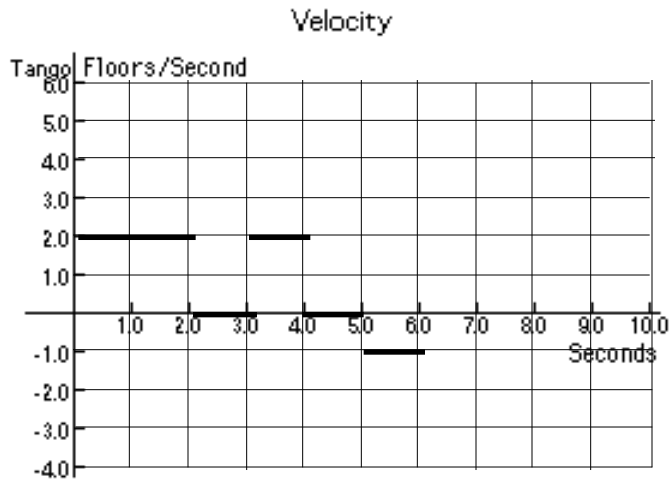
a. Draw the corresponding Position Graph for the Given Velocity graph.



- b. Where on the position graph is the elevator highest?
(circle the point)
- c. Where on the position graph is the elevator moving the fastest up?
(circle the region)
- d. Where on the position graph is the elevator moving the slowest up?
(circle the region)
- e. Where on the position graph is the elevator moving the fastest down?
(circle)

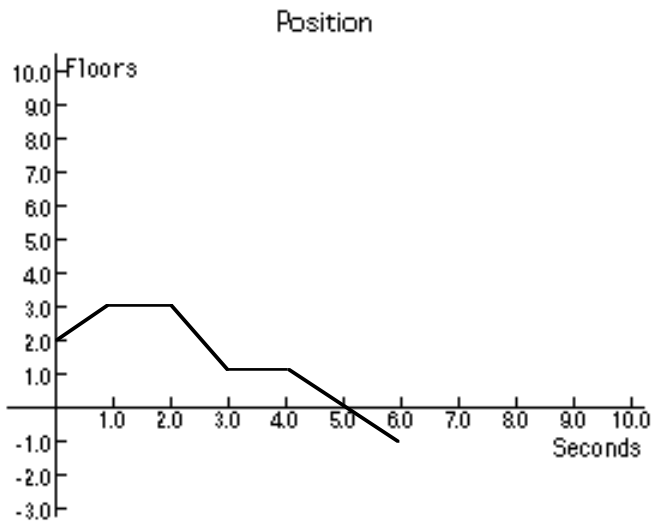
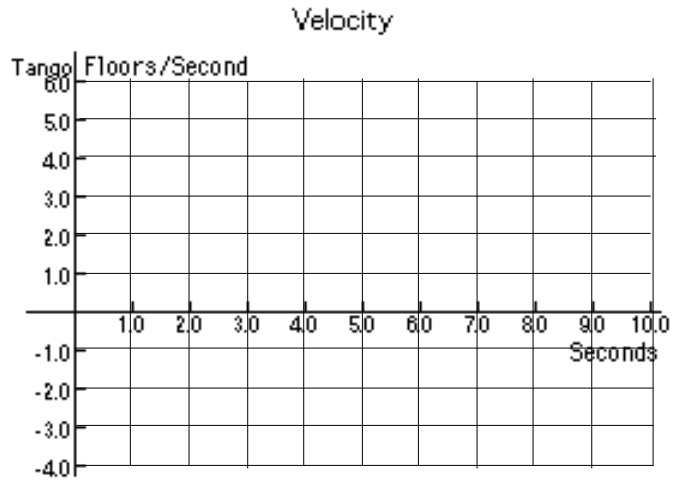
[3] The elevator starts on floor **negative three** and has the following velocity graph.

a. Draw the corresponding Position Graph for the Given Velocity graph.



- b. Where on the position graph is the elevator highest?
(circle the point)
- c. Where on the position graph is the elevator moving the fastest up?
(circle the region)
- d. Where on the position graph is the elevator moving the slowest up?
(circle the region)
- e. Where on the position graph is the elevator moving the fastest down?
(circle)

[4] Draw the corresponding Velocity vs. Time graph from the Given Position vs. Time Graph.



Activity One Handout

Name _____

ID Number (as assigned in class) _____

Measure and record your height and arm-span (distance from the left fingertip to right fingertip).

Height: _____ cm Arm-span: _____ cm

Record your measurements as an ordered pair. (,)

On your calculator, move your point to the location that corresponds to your measurements.

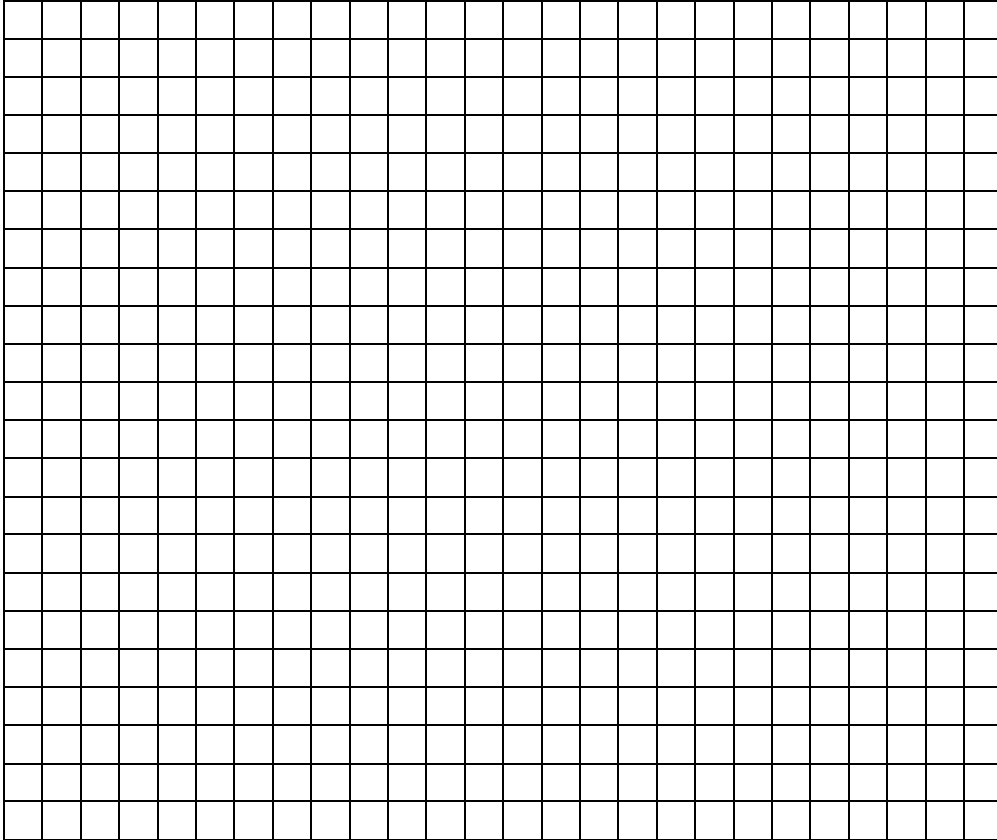
Write a function that you think best fits the class data:

Y = _____

What does your function suggest about the relationship between height and arm-span?

Sketch a graph of your function on the grid below.

Then sketch a function that you think is not as effective a fit as yours. Be sure to record the equation for this second line. Explain why it is not as good as yours.



What makes the other lines a better and worse fit, respectively, than yours?

Make a prediction about the arm-span of Shaquille O'Neal (213 cm tall). Make a prediction about the teacher's height, given her or his arm-span.

Activity Two Handout

Name: _____

What does the line do in this activity?

Exploration 1:

What was the goal or question?

What did you all do to get to this goal?

Exploration 2:

What was the goal or question?

What did you all do to get to this goal?

Exploration 3:

What was the goal or question?

What did you all do to get to this goal?

Exploration 4:

What was the goal or question?

What did you all do to get to this goal?

How do you think the Regression Line is being drawn? What properties does it seem to have?

What do you think R^2 measures? Why might it be a good measure of "fit"?