Creating “PacMan” With AgentCubes Online

Create the quintessential arcade game of the 80’s! Wind your way through a maze while eating pellets. Watch out for the ghosts!

Created by: Jeffrey Bush and Cathy Brand
University of Colorado, School of Education

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Lesson Objective:

- The students will apply the computational thinking patterns of user control, absorb, collaborative diffusion and Hill Climbing while creating a version of the 80’s arcade game, PacMan.

Prerequisite Skills:

- Students are presumed to have the following skills.
  - Create agents
  - Basic agent behavior including:
    - Key control
    - Random movement
    - Ending the game

Computational Thinking Patterns:

- User Control
- Collision
- Collaborative Diffusion
- Hill Climbing
- Polling

Length of Activity:

- Three to Five 30-45 minute lessons, although some students may advance more

Activity Description:

- Part 1: Create a basic world with a PacMan and randomly moving ghosts
- Part 2: Make the Ghosts chase the PacMan
- Part 3: Enhance the game so that the game is over when the pellets are gone
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PacMan (Continued)

Vocabulary/Definitions

Algorithm ............. a set of instructions designed to perform a specific task.

Attribute ............. a variable belonging to an agent (such as scent) also called a Local Variable by computer scientists.

Brackets .............. method of setting information apart using “[“ and “]”.

Broadcast .............. controllers send out a message.

Ghost .................. the agent that chases PacMan.

Collision .............. an event wherein two agents run into each other.

Diffusion .............. the process in which an attribute’s value (in this game, scent) is calculated based on the scent values of the neighboring agents.

Increment .............. to increase by one.

Hill Climbing ........ a specific form of searching/seeking technique, or algorithm, by which the seeking/searching agent uses information (the value of the scent agent attribute) embedded in the floor agent.

Method .............. a named set of rules evaluated by an agent in response to a message.

PacMan .................. the main character who eats the pellets as the user moves him around the world.

Parentheses .......... method of setting information apart using ( and ).

Polling .............. the process of asking agents to update a simulation property and then taking some action based on the value of the simulation property.

Propagate .............. the spreading of the scent.

Randomly .............. to occur in non-predictable ways.

Rule Order ............. the order in which rules are placed for each agent.

Simulation Property A named value that all agents can see and update.
General Teaching Strategies

Basic Philosophy

- The educational goal of these lessons is to learn and apply Computational Thinking Patterns in the context of a familiar game. Emphasis on these Computational Thinking Patterns is essential for student understanding.

- These lessons are also designed to give students positive experiences with and perceptions of computer science. Research shows that students turn away from high school and college computer science courses if they perceive it as boring, unrelated to what matters to them, and hard. We hope to change that by providing a fun, relevant and accessible computer science experience where they can personalize their experience to make computer science about them.

- Guided discovery is the central tenant of our curriculum. Direct instruction is sometimes used for aspects where students are learning the code for the first time; however, materials have been provided to ensure that students understand the programming concepts, as opposed to simply copying code.

- Whenever possible, students should try to come up with the steps on their own or in small groups, when differentiation and more structure is needed, we have more structured materials available.

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1 This information is supported by research found in the following documents:

Basawapatna, A. R., Koh, K. H., & Repenning, A. (2010, June). Using scalable game design to teach computer science from middle school to graduate school. In Proceedings of the fifteenth annual conference on Innovation and technology in computer science education (pp. 224-228). ACM.


PacMan (Continued)

- Student materials are available for each portion of the game design. These materials are intended to be used in addition to teacher materials, which provide prompts and discussion points.

- Students may become frustrated with too little teacher support, THIS IS OK! A little frustration and moving at a slower pace is well worth the deeper conceptual understanding that comes with guided discovery.

Guided Discovery Process

- **Model the process** rather than just giving students the answer. As a teacher, focus on explanations and discussions of **WHY** something works or doesn’t work and let the students figure out **HOW** to make it work.

- Building the game on your own, before trying it with your class will enable you to see which steps may challenge or confuse your students.

- Have students work through problems independently or in small groups. Ask directing questions or give helpful suggestions, but **provide only minimal assistance** and only when needed to overcome obstacles.

- **Group work is your friend**! It is common for computer programmers to talk through problems with one another, and to use code snippets found from other programs and other programmers. Talking through coding problems enables students to think more critically about Computational Thinking Patterns, as well as the steps needed to solve a problem.

- Additionally, seeing how others solved an issue with code helps students realize that problems often have multiple solution strategies, and that some solutions might be more effective than others. Also group work lets them see that they are not alone and that others have similar and different questions, struggles, inspirations and perspectives.

- Recognize that programming is largely a process of **trial and error**, particularly when students are first learning. It is helpful to encourage this mindset with your students.

- “What have you tried so far? Why didn’t it work?” is a great way to start any troubleshooting discussion.
PacMan (Continued)

Building Blocks

- Each project is designed to build on the prior one. Very little student support is provided where expertise has already been created. Conversely, material that is new has more support.

- Be sure to talk through the building blocks (especially for PacMan in the area of diffusion and hill climbing) as these Computational Thinking Patterns will appear often in future games and simulations.

- Encourage discussion and reflection on these Computational Thinking patterns. Small group or whole class discussion relating Computational Thinking patterns to the outside world can be super productive.

- Remember that conceptual understanding takes time, and it may be necessary to review these concepts multiple times, using different examples, so that all students can be successful.

Support Learning

- Research shows that game design is associated with engaged students, and engaged students show higher levels on conceptual understanding. Allowing students to personalize their games aids in this engagement and motivation. Plus, it makes grading and reviewing games more fun for you.

- Coding may be difficult for some students, and all students are likely to be frustrated at times when the code does not produce the expected results. Praise students for sticking with the troubleshooting process and encourage them to share what they learned with others.

- Consider students who are ahead to the role of “code ambassadors” to walk around and help their peers with coding questions.

- Be sure to communicate that the process is more important than the answer, and that coding of a project often takes time. Do not place pressure on your students to ‘hurry up’ and resort to giving them the code. The process of figuring it out on his/her own will result in much stronger conceptual understanding.
Differentiated Instruction

Note that there are many vocabulary words in this lesson that may be new for your students. Take time to define those words. Using the words in context often will reinforce their meaning for the students.

- **Students who need a challenge:** Some students with more fluency in programming may finish this very quickly – be prepared for by having challenge activity materials ready in advance.

- **Students who need more assistance:** Other students (especially those with no Frogger experience) may struggle a bit more. There are two options for differentiated instruction. Consider the needs of the student and the class as you decide which will work best.
  - Option 1: Pair a struggling student with an experienced student
  - Option 2: Provide student with a tutorial found on the Scalable Game Design Wiki\(^2\). Note that tutorials do not support independent thinking and should only be used when absolutely needed.
  - Vocabulary for ELL Students: Generate, Absorb, Collision, Agent, Grotto, Depiction, Condition, Transport
  - Time management issues: While students can be more engaged when they design their own agents, some students can spend too much time on this design or find it frustrating.

- **Note:** Two student packets are available. The STANDARD packet is for students with some basic knowledge of AgentCubes Online. The ALTERNATIVE packet is for students with NO prior AgentCubes Online experience who may need more support. The ALTERNATIVE packet should NOT be used for most students as it significantly reduces the active thinking processes.

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Teacher Instructions:

Part 1 – Basic Game

Teaching Suggestions

Task your students with creating a new game. The basic features of the game are as follows:

The player controls Pac-Man through a maze, eating pellets. When all pellets are eaten, PacMan is taken to the next stage. Enemy ghosts roam the maze, chasing PacMan and trying to catch him. PacMan dies if an enemy touches him.

Give students time to discuss the features of this game in pairs or small groups. Have them share their responses together.

Consider these prompts:

- How is this game similar to Frogger? Different than Frogger?
- What are the skills that you learned from Frogger that you might need here?
- What agents will we need?
- How do you think you might be able to program the Ghosts to move randomly (and, what does “randomly” mean)?
- What would make the game more challenging? Less challenging?

Once the students have had a few minutes to think through these prompts, provide them with Handout 1 so that they may begin work.

You may have some students who have never worked with AgentCubes Online. Use Handout 1A for those students.

The student pages can be found on page 3 of the STANDARD packet and page 3 of the ALTERNATIVE packet.

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Student Handout 1:
Part I - Basic Game

Initial Story: Create the quintessential arcade game of the 80’s! Wind your way through a maze while eating pellets. Watch out for the ghosts!

Create these Agents and the world or [clone our blank game](https://www.agentcubesonline.com/project/902095) with the agents already designed:

- PacMan
- Ghost with two depictions
- Pellet
- Ground
- Wall
- 16x21 World with PacMan, Red & Green Ghosts

Turn to your partner and discuss:
- Do you want ground under the walls?
- Why would it matter?
- What could go wrong?

Create the following BEHAVIORS for your agents:

**Step 1: Ghost:**
Program the Ghost to move randomly on the ground and the pellets. Here is the first rule that allows the ghost to move on the ground. What should the second rule look like? Be mindful of what will happen if both commands have the same time for “once every”. (See Appendix I: [Guidance on Ghost’s Random Movement](#) for more help. It is found on the last page of your lesson.)
Step 2: PacMan:
- Make four rules so your agent moves in the right directions when each arrow key is typed just like the frog in Frogger (cursor control).

Step 3: Prevent your PacMan from going through walls
Work with the person next to you to figure out how to prevent the PacMan from walking into a wall. First come up with an if…then sentence to describe the behavior, then write/test the code.

Programming Tip: Use the NOT button below the method to add a NOT to a condition:

Scaffolding Tip: if they need help, encourage students to use if…and…then…sentences

Step 4: Enable your PacMan to ‘eat’ the pellets
Work with the person next to you to figure out how to have the PacMan eat the pellets.

Collision
The event that occurs when two agents run into one another

IF the PacMan and the Pellet COLLIDE,
THEN the Pellet should ERASE

If the PacMan and the Ghost COLLIDE,
THEN the Game is OVER

Step 5: Game Over when the PacMan is next to a Ghost
Show a message so that the player knows why the game ended.

Very Important Tip: Put or in your Game over rule.
If you forget to do this, AgentCubes Online will do the game ending rule over and over until you are able to type the Return Key to click the OK on the dialog box and then immediately after use the mouse to click on the stop game button (the red square).
If you cannot click on the stop game button before the dialog box reappears, you must shut down and restart your computer and then restart AgentCubes Online.
Step 5: Test your game

Play your game by pressing the green arrow.
- Does your PacMan move in all four directions?
- Does your PacMan stay on the floor (and not go through walls)
- Do the ghosts move randomly?
- Does your PacMan eat pellets?
- Does the game end when the PacMan is next to the Ghost?
- Did you show a message to tell the player why the game ended?
Student Handout 1A:

Part I - Basic Game

Initial Story: Create the quintessential arcade game of the 80’s! Wind your way through a maze while eating pellets. Watch out for the ghosts!

Create these Agents and the world or clone our blank game with the agents already designed:

https://www.agentcubesonline.com/project/902095

You are about to create your first game. Because this is new to you, we will give you some parts of the code. Be careful – you will have to find the patterns to create the rest of the code. If you get stuck, check in with a nearby student to get some help!
Launch AgentCubes Online and Create a New Game

**Step 1:**
Create Project

Go to [https://www.agentcubesonline.com/](https://www.agentcubesonline.com/)
If you have an account, click on the Login link. If not, click on the Sign up link.

After you login, click on the blue “New project” link below your login name.

**Step 2:**
Name the Project

Name it PacMan and click Create project.

**Step 3**
Create the agents for PacMan

Click on the +Agent button.
Choose Inflatable Icon, then Miscellaneous, then “packy” to get a picture of PacMan.

Type PacMan in the Agent Name box and click on the OK button.
**Step 4**

1. To edit the drawing of PacMan, double click on the picture next to the agent’s name.
2. Use the drawing tools to edit the image or click on the Clear button to erase the picture.
3. Use the pencil and the color picker (black square in the center of the row of drawing tools on the left of the 2D drawing) to draw a new picture.
4. Click on the color picker to choose a new color.
5. Use the bucket tool to fill in the outline with color.
6. Click on the + to inflate your drawing into a 3D image.
7. Use the Ceiling slider to flatten it.
8. Click the upright box to stand PacMan up.
9. Pick front and back connected next to the word “surfaces” so PacMan has 2 sides.

**Step 5**

Create the Ghost.

If you go to the Miscellaneous category under Inflatable Icon, there is an agent named “ghosty”.

You can edit the drawing and change the color or draw your own ghost.

Here is a PacMan Ghost like the ones in the original game.
### PacMan (Continued)

<table>
<thead>
<tr>
<th>Step 6</th>
<th>Make a second shape for your Ghost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click on the agent name, then click on the +Shape button at the bottom of the window.</td>
</tr>
<tr>
<td></td>
<td>Give your new shape a name and click OK</td>
</tr>
<tr>
<td></td>
<td>Then double click on the picture next to the name of the new shape and edit it.</td>
</tr>
<tr>
<td></td>
<td>Change the ghost color so this shape looks different from the original ghost.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 7</th>
<th>Create the Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click +Agent and name it Wall</td>
</tr>
<tr>
<td></td>
<td>Select Cube and then pick a cube that you like.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 8</th>
<th>Create the Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click +Agent and name it Ground</td>
</tr>
<tr>
<td></td>
<td>Select Tile and pick one that you like.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 9</th>
<th>Create the Pellet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click +Agent and name it Pellet.</td>
</tr>
<tr>
<td></td>
<td>Pick an inflatable icon, erase the picture, draw a pellet, use + to inflate &amp; ceiling to flatten it.</td>
</tr>
</tbody>
</table>
### PacMan (Continued)

#### Step 10
Make a Level 1 World

Click on the ‘+’ next to World

When the New World box appears, type the name into the Name box.

We recommend your world has at least 16 rows and 21 columns.

#### Step 11
Design your World

Use the dotted rectangle tool to place a rectangle of walls on the World.

Use the same tool to place the walls of the maze.

Then place ground where there is not maze.

Place a rectangle of pellets on top of the ground.

Use the pencil to draw single agents (PacMan, the Ghosts).

The Ghosts are in the rectangular area with an opening.

#### Step 12
Save your World every time you make a change that you wish to keep.

When agents get moved around after playing or testing, click on the Reset button on the top bar of AgentCubes Online to return to the saved version of your World!
### Time to Create Behaviors for your Agents

<table>
<thead>
<tr>
<th>Step 13</th>
<th>Create an agent behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Click on an agent</strong> and its behavior window will appear below the world.</td>
<td></td>
</tr>
<tr>
<td>You are going to drop and drag the conditions (on the left) and the actions (on the right) to create the rules.</td>
<td></td>
</tr>
</tbody>
</table>

**This rule says:**

- IF the user **presses the up arrow**, AND I Do NOT See a Wall in the up direction, THEN my PacMan will move UP.

**Tip:** Click on the See condition, then the NOT button at the bottom of the window to make the NOT See condition.

Create 3 more rules to make PacMan move right, left, and down.

**NOTE:** Click on the rule you made, then click on the +RULE button at the bottom of the window to create each new rule.

<table>
<thead>
<tr>
<th>Step 14</th>
<th>Program the PacMan to eat the pellets.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First, take a moment to think about the PacMan and the Pellets</strong> When the PacMan collides with the Pellets, then the Pellet disappears, making it look like the PacMan ate it.</td>
<td></td>
</tr>
<tr>
<td><strong>Take a look at this code when the Pellet sees the PacMan above or below him:</strong> It says…</td>
<td></td>
</tr>
</tbody>
</table>

**IF I see a PacMan above or below me**

**THEN... erase myself (the pellet)**
PacMan (Continued)

<table>
<thead>
<tr>
<th>Step 15</th>
<th>Program the Ghosts to move randomly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Play with adding a wait time before erase. What happens when wait before adding the pellet? Choose a wait time (or no wait time) that you think makes the eating behavior look the way you want it.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 16</th>
<th>Create rule to end the game when the PacMan is next to the Ghost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Click on PacMan and add this rule.</td>
<td></td>
</tr>
</tbody>
</table>

**How can you make the Ghost move faster or slower? Experiment with the number in the once every condition.**

*The ghost should also move on the pellets so add a second rule!*

Be mindful of what will happen if both commands have the same time for “once every”. (see Appendix I: [Guidance on Ghost’s Random Movement](#) for more help)

<table>
<thead>
<tr>
<th>Very Important Tip: Put and/or in your Game ending rule.</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you forget to do this, <strong>AgentCubes Online will do the game ending rule over and over</strong> until you are able to type the Return Key to click the OK on the dialog box and then immediately after use the mouse to click on the stop game button (the red square).</td>
</tr>
</tbody>
</table>

If you cannot click on the stop game button before the dialog box appears, you must close the browser window, then open a new browser window, go to AgentCubes Online, find your project and click on the edit button so it opens.
Teacher Instructions: Part 2 – Making the Ghost Chase the PacMan

Overview:
In this part of the project, students will change the game to make it harder to win and more interesting. Instead of the Ghost moving randomly, the Ghost will now actually move toward the PacMan.

There are two Computational Thinking Patterns that will be included in this lesson:

- Diffusion: The PacMan leaves a scent on the floor and the pellets. The scent will spread along the floor and pellets…this is the same as saying the floor and pellets will DIFFUSE the scent.

- Hill Climbing: This is a particular way of ‘SEEKING’ a scent. This code makes the Ghost check the scent in all four directions, and follow the strongest scent.

These computational thinking patterns require AGENT ATTRIBUTES.

An Agent Attribute is a VARIABLE that can be used LOCALLY (by an individual agent). Note that AgentCubes Online also has Simulation Properties, or variables that can be used GLOBALLY (seen by ALL agents).

Instruction:
Talk to your students about the Ghost.

Consider these prompts:

- Does the Ghost really ‘chase’ the PacMan? Why or why not?
- Why would we change the game so that he really did chase the PacMan?
- How could we change the game so that he could chase the PacMan?

[Give students a minute or two to discuss this with the person next to them. Then solicit their ideas. Remember that allowing students to discuss new concepts will aid their conceptual understanding of those concepts.]
Any of these videos can be used with the class to provide different views of how diffusion of scent and subsequent “hill-climbing” actions are used by different animals.

https://www.youtube.com/watch?v=XXXU0uKLWo0

This YouTube video explains how dogs use scent for search and rescue.

https://www.youtube.com/watch?v=gU9CQT-snIo

A more scientific explanation of how to determine if sharks can smell blood in the water.

https://www.youtube.com/watch?v=uqv9EmfkkGF

**Explain:** In Part I of this project, the Ghost agent simply moved around randomly on the ground. In this next phase of the design, the Ghost will intelligently seek the PacMan agent using a computational thinking pattern called “Hill Climbing.”

Imagine the PacMan agent emits a scent. The scent will be propagated by the ground agents using a computational thinking pattern called “diffusion.” Diffusion is a fundamental physical process by which matter moves down a gradient from highest to lowest concentrations. The closer to the source of the scent, the greater its value. Hill climbing, which is an algorithm to find the direction in which the scent is strongest, is then used by the ghosts to chase the PacMan.

You may use the Diffusion PowerPoint Presentation to support understanding of these concepts.

Students have a handout that accompanies this lesson. The following screen shots of code are for the teacher, but this information should not be shared fully with the student unless needed.

First, let’s make sure PacMan gives off a scent. To do this, we need to set the value of an attribute named “S” which stands for Scent. The scent attribute is associated with PacMan and is set when the PacMan is created by being drawn on the world. This guarantees that the scent attribute always has a meaningful value when the game starts running.

To set the value of s this way, we must click on the +Method button at the bottom of the AgentCubes Online window and make a new method. Click on the word “on” in the upper left corner of your new method and change it to “when-creating-new agent”.

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4 Available on the Scalable Game Design Wiki. Use Quick Links>>Teacher>>Lesson Plans
This method of setting an agent attribute value ONLY works if the agent is erased and redrawn on the world after the when-creating-new-agent method is added to its rules.

Erase your PacMan agent and redraw it, then SAVE the world so that you save the new PacMan with \( s \) set to 1000.

If you forget to save the world, reloading the world will bring back your original PacMan that did not have an \( s \) attribute and the rest of the code that makes the ghosts chase PacMan will not work.

Check that PacMan’s \( S \) attribute is set to 1000 by double clicking on PacMan with the big arrow tool. PacMan’s agent attribute window will appear showing the value of \( s \) if it has been set.

Both the Pellet and the Background diffuse the scent so that the Ghosts can identify the direction of the strongest scent. The value of the agent attribute \( s \) belonging to any pellet or ground agent is the average of the values of the \( s \) agent attributes of the four surrounding agents:

\[
s = 0.25 \times (s_{\text{left}} + s_{\text{right}} + s_{\text{up}} + s_{\text{down}})
\]

Every 0.5 seconds, the Ghost will follow the scent by determining which direction is strongest, up, down, left or right. (Note, only the first of four rules is shown below).
More realistic Ghost catching

Have you noticed how your Ghost will “catch” PacMan when it is next to him, or even diagonal from him. Ask your students how they could now change the lose condition for when the ghosts catch PacMan to make the Ghosts only “catch” him when they are above him?

Ask them why this didn’t work before you added Hill Climbing and have them discuss with a partner.

**Answer:** when ghosts were moving randomly on the ground they would not move onto Pac-Man so the only way to make them “catch” him was by being next to him. Now that they move towards PacMan they can be on top. Changing the lose condition to ”if stacked above or below PacMan” lets PacMan be next to Ghosts but then lose when he moves onto them or they move on to him.

**Having students experiment with differences between staked above, below and above or below is a good critical thinking exercise**

Shortcut for Hill Climbing

AgentCubes Online has an even better way to handle the process of Hill Climbing which should be shared with students AFTER they understand the process of Hill Climbing. **It is worth the time to create the Ghost’s Hill Climbing rules before using the shortcut to ensure that students understand the Hill Climbing computational thinking pattern.** The use of the Hill Climbing action (see rule below) makes future extensions in the game, such as having the ghosts run from the PacMan, easier.

A learner may find the message action a helpful reminder of what the hill climb action does.
However, this behavior could be programmed in a single rule as follows:

This code is a shortcut for checking in all four directions (defined as Von Neumann’s Neighborhood...students could choose to check in eight directions using Moore’s Neighborhood!

You could then extend the learning by asking students to compare what happens when the ghosts search 4 directions around themselves versus searching 8 directions around themselves. Have the students do some tests to see which method catches PacMan more rapidly.

http://www.conwaylife.com/wiki/Von_Neumann_neighbourhood
There are many resources available on the Scalable Game Design Wiki to support the computational thinking patterns of Diffusion and Hill Climbing. Take time before the lesson to check these out and determine how they might support your students in better understanding these concepts.

http://sgd.cs.colorado.edu/wiki/Collaborative_Diffusion

Teacher Tip:
If students saved the game before the scent could diffuse throughout the world then the ghosts will move through walls at the start. This is a great opportunity for them to think about why they might be observing this behavior and what they can do to fix it.

Using a plot action to visualize $S$ values:

Plotting can be used to look at values in simulations. PacMan offers an opportunity to introduce the concept to students.

Students can use the plot action to visualize the value of $S$ in the ground agents and the pellets. The plot action will plot the values of $S$ logarithmically in a 3D surface above the world. The peak on the plot represents the highest value of $S$ in the world. The peak should be over PacMan since his $S$ value is 1000.

Make a new rule at the bottom of PacMan’s while-running method and add the plot action:

To make the plot action work

1. This rule must be the last rule in PacMan’s while-running method! Why? What is the effect of the blank if condition?
2. Enter “$S$” for the name of the agent attribute.
3. Edit the row and column numbers so that values from the entire world are plotted. Remember that the world size for PacMan is 16 rows and 21 columns. Computer scientists always count from 0 to (Number – 1), in this case, rows 0 to 9 and columns 0 to 20. If you changed the default size, you must count from 0 to (New Size -1).
4. Pick a color for the plot that will show up against your background.
5. Change the elevation to 1.0.
6. Make sure to choose “logarithmically” as the plot type. This option works better than plotting linearly when some of the values are quite large and others are very close to zero.
7. Make a test world that just has a layer of ground agents, a layer of pellets, PacMan and one ghost.

8. Use the Rotate tool to tilt your world so that it is nearly horizontal and you can see the agents below the plot surface.
9. Run the game and move PacMan around. The peak, which represents the high value, will follow him. The ghost will move towards the high value (the peak).
10. Add a couple of rows of wall agents. What happens to the shape of the plot when the walls are added?
11. The walls have no S value so the plot gets some wrinkles and valleys.
12. Watch the ghost go around the walls following the increasing S values towards PacMan!
13. Now run your PacMan world with the complete maze on it and see what happens to the plot of the S values!
14. You may find that reloading the world does not erase the plot surface. Reload your browser window or click on the AgentCubes Online logo in the upper right corner of the AgentCubes Online window and click the edit button for your project again.

Figure 1. Plot of the S values with peak over PacMan.
Why is there a low spot over the ghost? Does the ghost have an S value?

Figure 2. Plot of the S values with some walls in the world.

PacMan and the ghost are under the peak. Why is there a valley over the wall?

Pass out Student Handout 2
The student pages can be found on page 6 of the STANDARD packet and page 10 of the ALTERNATIVE packet. The troubleshooting guide is found on pages 12 and 16 respectively of the standard and alternative packets.
So far, your Ghost just moves randomly, either just on the floor, or on the floor and the pellets...he doesn’t actually chase the PacMan, does he? That’s about to change!

The Ghost will intelligently seek the PacMan agent using a computational thinking pattern called “searching.” In this instance, we will use a specific method of searching called Hill Climbing. Imagine the PacMan agent emits a scent. Hill climbing is a procedure or algorithm to find the direction in which the scent is strongest.

The scent will spread out, or be propagated, by the ground agents using a computational thinking pattern called “diffusion.” Diffusion is a fundamental process (physical, biological, and social) by which objects move from areas of highest concentration to areas of lowest concentrations. The closer to the source of the scent, the greater its value.

This phase of the project introduces the concept of an “agent attribute,” which is unique information that is stored within each occurrence of an agent. Computer scientists call this agent attribute a local variable.

**Step 1:** The best way to initialize PacMan’s S agent attribute is to set it when PacMan is drawn on the world because then PacMan’s attribute will always start at the same value.

To do this, create a new Method by clicking on the +Method button. Click on the word “on” in the new method’s black and yellow striped tape and change the label from “on” to “when-creating-new-agent”.

Your when-creating-new-agent method should look as follows:

If you use this method to set PacMan’s S attribute, make sure that you erase and redraw PacMan and then SAVE the World.

**Important Note:** If you forget to save the world, PacMan may not have any value set for S when the world is reloaded.
Checking the Value of PacMan’s S agent attribute:

1. Double click on PacMan with the big arrow tool.

2. You should see this window appear:

3. If S is not visible in the window, it did not get set to a value yet.
4. Erase and redraw PacMan and then save the world. Then S should appear in the Attributes window.

Step 2:
Now, since the scent is diffusing, or spreading out, we need to find the average of the scent from the area around a ground agent or a pellet agent. Think of it as the smells are coming in from the North, South, East and West. The smell in the center, then, is the average of these four smells.

How will you create that programmatically?

**Diffuse the scent using the pellet agents**

The pellet agent will have the behavior below; the single action is to calculate and store the average of the four surrounding agents’ agent attributes. Remember, you named the agent attribute “S” (for scent).

The “set” action sets each pellet agent’s attribute “S” to the average of the attributes in the agents above, below, and on each side:

\[ S = 0.25 \times (s[\text{up}]+s[\text{down}]+s[\text{right}]+s[\text{left}]) \]

**Why do we multiply by 0.25?**

When you find the average of a set of numbers, you add them up and divide by the number of numbers.

In this case, dividing by 4 is the same as multiplying by \( \frac{1}{4} \), which equals 0.25.
NOW…diffuse the scent across the ground by adding a rule to the ground agents!

Match both the parentheses “(” and the brackets “[” as shown in the equation.

Step 3: For the Ghost to know which way to walk, he has to determine where the scent is the strongest. We call this HILL CLIMBING. If this were real life, he would smell up, smell down, smell left and smell right. Wherever the smell was strongest, he would walk in that direction. We need to program the Ghost to do this.

We will create a METHOD for the Ghost to follow a set of rules.

Take a look at the programming below.

The rule in the while running method says “ONCE EVERY 0.5 seconds, follow the Chase PacMan procedure”.

The rule in the Chase PacMan method says “IF the smell above you is greater than or equal to any of the other smells in different directions (down, left or right), THEN move up.”
Now, add the three more rules to the Chase Pacman method so that the Ghost knows what to do if the smell down (S[down]) is greater. What if the smell to the left is greater? What about the smell to the right?

Run your game to see if the Ghost chases the PacMan!
If it isn’t working, check the following:
  o Erase and redraw PacMan, then save the world so the initial value of S is saved.
  o In the Chaser’s rules, the method name must be the same in the message action and the black and yellow striped method name tag of the hill climbing method!
  o Use of parentheses “(“ and brackets “[“ in the ground and pellet agent rules must be correct. Check the picture of the ground agent’s equation 2 pages ago and compare it to the equations in your ground and pellet agents.
  o Check your hill climbing rules again and make sure that the arrows in the actions point the correct direction and that the conditions for each rule are correct.
**More realistic Ghost catching**

Have you noticed how your Ghost will “catch” PacMan when it is next to him, or even diagonal from him. How could you now change your lose condition for when the ghosts catch PacMan to make the Ghosts only “catch” him when they are above him? Give it a try.

Why didn’t this work before you added Hill Climbing? Discuss with a partner.

**Shortcut for Hill Climbing**

AgentCubes Online has an even better way to handle the process of Hill Climbing. The use of the Hill Climbing action (see rule below) makes future extensions in the game, such as having the ghosts run from the PacMan, easier.

There is a single action, hill climb, that replaces all the rules in the Chase PacMan method.

It is possible to eliminate the Chase PacMan method by simply putting the hill climb action in the rule in the ghost’s while running method.
Test out the options in the hill climb action. 
What happens if the ghosts search in 8 directions? 
Can PacMan escape? 
Would it help to use fewer ghosts? 
After you have run your game several times, choose whether your ghosts will search in 4 or 8 directions and decide on the number of ghosts in your game.
Student Handout:
Troubleshooting Guide for Diffusion and Hill Climbing –
Part 1: Tracking the Ghost One Step at a Time

To determine what is happening in your game, it is helpful to look at the agent attributes.

1. On your world, click run until the ghosts move out of the box, and then click stop.
2. Running the game briefly made PacMan’s scent diffuse across the world.
3. Check PacMan’s s attribute by double clicking on him with the big arrow tool.

4. This window will appear:
5. Make sure that you erased and redrew PacMan on the world and then SAVED the world.
6. To see how PacMan’s scent (the value of S) has diffused, double click with the big arrow tool anywhere on the ground or on a pellet.
7. A window will appear that lists the S attribute value for that agent.
8. Click around the world. Is S biggest close to PacMan and smaller far away from PacMan? Before you do so, MAKE SURE YOU TEMPORARILY REMOVE THE “once every 0.5” seconds” so you get more immediate feedback.

Check the attributes of the four boxes around the Ghost (up, down, left and right) and then single-step the game using this button so you can see if your Ghost is moving towards the agent with the largest S value.

If the Ghost moves the wrong way or does not move, go back and check your rules in the Chase PacMan method. Compare your rules with a friend’s rules.

- Are the conditions correct?
- Are the arrows in the move actions correct?
- If you used the hill climb action, check that you changed “value” in the hill climb action to S.
Now put the “once every 0.5 seconds” back in so the ghosts don’t move too fast

9. You can also try erasing all but one of the ghosts to see if it moves towards PacMan. This helps because the Ghosts do not propagate the scent.

Critical thinking question: Why don’t you want the Ghosts to propagate the scent? What would happen if they do?

Part2: Using a plot action to visualize S values:
We can use the plot action to visualize the value of S in the ground agents and the pellets. The plot action will plot the values of S in a 3D surface above the world. The peak on the plot represents the highest value of S in the world. What agent should be under the peak?
Make a new rule at the bottom of PacMan’s while-running method and add the plot action:

To make the plot action work
1. This rule must be the last rule in PacMan’s while-running method!
2. Enter “S” for the name of the agent attribute.
3. Edit the row and column numbers so that values from the entire world are plotted.
   Remember that the world size for PacMan is 16 rows and 21 columns. Computer scientists always count from 0 to (Number – 1), in this case, rows 0 to 15 and columns 0 to 20. If you changed the default size, you must count from 0 to (New Size -1).
4. Pick a color for the plot that will show up against your background.
5. Change the elevation to 1.0.
6. Make sure to choose “logarithmically” as the plot type. This option works better than plotting linearly when some of the values are quite large and others are very close to zero.
7. Make a test world that just has a layer of ground agents, a layer of pellets, PacMan and one ghost.
8. Use the Rotate tool to tilt your world so that it is nearly horizontal and you can see the agents below the plot surface.
9. Run the game and move PacMan around. The peak, which represents the high value, will follow him. The ghost will move towards the high value (the peak).
10. Add a couple of rows of wall agents. What happens to the shape of the plot when the walls are added?
11. The walls have no S value so the plot gets some wrinkles and valleys.
12. Watch the ghost go around the walls following the increasing S values towards PacMan!
13. Now run your PacMan world with the complete maze on it and see what happens to the plot of the S values!
14. You may find that reloading the world does not erase the plot surface. Reload your browser window or click on the AgentCubes Online logo in the upper right corner of the AgentCubes Online window and click the edit button for your project again.

Figure 1. Plot of the S values with peak over PacMan.

Why is there a low spot over the ghost? Does the ghost have an S value?
Figure 2. Plot of the $S$ values with some walls in the world.

PacMan and the ghost are under the peak. Why is there a valley over the wall?
Teacher Instructions
Part 3 – Making the game more sophisticated – Polling and Broadcast

Background:
In a classroom, when students are working on an assignment, teachers regularly ‘poll’ the room to see if everyone is done yet. A teacher does this by asking students to raise their hand if they are still working. If no one raises a hand, the teacher knows everyone is done. Once everyone is done, the assignment is finished. Students will use this same concept to change their game to make it more challenging.

Introduction to students:
Using the example of the classroom, guide your students through a discussion of how to poll for answers. Now, tell them they are going to use this same concept to change their game. This time, the game looks like this:

In our game, the game ends when PacMan is next to a ghost. Now we need to find a way to win the game when all of the pellets are gone.

Give students a couple of minutes to discuss this programming activity.

Consider these prompts:
- Who will poll (look to see if there are still more pellets to be collected)
- What stops the game?
- What steps (code) will change?

[Give students a minute or two to discuss this with the person next to them. Then solicit their ideas.]

Students will struggle with the idea of who polls. Introduce the idea of a controller, an agent that is responsible for tracking the number of pellets left on the world. Remind the students that they should take time to think through each programming step so they can use these skills later.

Hand out handout 3
No code is provided in the teacher instructions as all code is provided for students.
The student pages can be found on page 16 of the STANDARD packet and page 20 of the ALTERNATIVE packet.
Student Handout 3 Part 3:
Making the game more sophisticated – Polling and Broadcast

In this enhancement to the PacMan project, the PacMan must “eat” all of the pellets in order to win. Polling will tell us when all the pellets are gone and PacMan has won.

Polling uses a simulation property, also called a global variable by computer scientists, which is a piece of information that all agents in the simulation or game may check or set if they have the correct rules. A controller agent does the polling by sending out a message at intervals to all the agents that must be counted. These agents respond by adding one to the simulation property. The controller determines when all the pellet agents are gone and PacMan has won.

The teacher has given an assignment to the class and wants to know if everyone is finished. She says to the class, “Put your hand up if you are still working.” Hands go up. She counts them – there are five students still working. “Okay, put your hands down and keep working.”

A few minutes later, she does it again. She says to the class, “Put your hand up if you are still working.” Hands go up. She counts them – there are two students still working. “Okay, put your hands down and keep working.”

A few minutes later, she does it again. She says to the class, “Put your hand up if you are still working.” This time, no hands go up. “Everyone is done, put your books away.”

That’s what this programming will look like.

The Controller will say, “Pellet count starts at zero” (like the classroom, no hands are up when the teacher asks who is still working).

When the pellets ‘hear’ the Controller ask (broadcast) the question, the pellets respond back (raise their hands).

The Controller counts the pellets. If the answer is more than zero, nothing happens and the game continues. If the answer is zero (meaning that there are no remaining pellets on the board), the game ends.

Definition: Computer scientists call the process of making a decision by sending a message to multiple recipients and checking responses polling.
PacMan (Continued)

Step 1: Create the Pellets simulation property as described in the green box below.

Step 2: Create the Controller agent.
- Use +Agent to make a Controller agent and choose any image.
- Place the Controller agent on top of a wall in your PacMan world and SAVE the world!

Step 3: Add a rule to the Controller agent’s while running method.
1. Set the number of pellets to zero. (this is like the teacher saying “hands down”)
   \[
   \text{Set } @\text{Pellets to zero}
   \]
2. Ask the pellets if they are still on the world
   \[
   \text{Broadcast to Pellet agents to do “Count”}
   \]
3. Check the number of pellets to see if the game is done.
   \[
   \text{Send a Checkwin message to myself.}
   \]

Step 4: Program the Controller agent’s Checkwin method.
- If there are no pellets left, tell the player that PacMan won and stop the game.

Step 5: Program the Pellet Agent’s Count method.
1. Make a new method for the Pellet agent.
2. Name it Count.
   The name must exactly match the name broadcast by the Controller.
3. Add a rule with an action that sets the value of “@Pellets” to “@Pellets + 1”.
   This is how programmers add 1 to a number.

Try setting up these rules now!

How do Simulation Properties Work?
1. Simulation properties may be added, saved or deleted in the Simulation Properties window.
2. Open this window by clicking on the gear button on the top right side of the AgentCubes Online window and choosing “Show Simulation Properties”.
3. Make the Pellets simulation property by clicking on the + button at the bottom of the simulation properties window and typing the name “Pellets”.
4. Click on the Save button so that the new simulation property is saved!
5. The value of a simulation property can be changed or checked by any of the agents in the game or world.
6. All conditions and actions which check or change the value of a simulation property must place an “@” before the simulation property name.
Count is not part of the continually running “While Running” method. It must be a separate method since it only runs when called by the controller agent.

**Check your program:**

Here is the Controller agent behavior with the rule in the while running method that makes the pellet agents count themselves and the new Checkwin method that ends the game if PacMan has eaten all the pellets:

Here is the Pellet behavior with the new Count method that allows each Pellet agent to add 1 to the Pellets simulation property:
The Bigger Picture: Communication between Agents

Polling introduces a technique that allows agents to create a complex behavior by cooperating: a particular set of conditions cause one type of agent to send a message to another type of agent to do a named method that contains a special set of rules. Count was the special method in the polling example.

This type of communication between different types of agents can be used to create interesting games. For example, if PacMan eats a power pill, then PacMan can broadcast a message to all ghosts to “Get_Scared”. The Get_Scared method can change the ghosts’ appearance so that they look different as they run away instead of chasing PacMan. Or the Traveler in Journey can fire ice arrows at Chasers. When an ice arrow hits a Chaser, it sends the Chaser agent a message that makes it freeze if it is unfrozen. Frozen chasers cannot move so the Traveler can collect the treasures without being caught by the Chaser.

However, when the goal is just to count up the number of agents and stick the value in a simulation property, AgentCubes Online has a simpler method for the controller to do this:

These two actions have been deleted from the controller’s while running method:

And replaced by this action:

The set action contains a specialized communication between the controller and the Pellet agents, the agents_of_type(“Pellet”) message, which makes the pellets count themselves without the need for us to code a separate count method.

You learned polling so that you would understand how to make different types of agents communicate. But there is usually more than one solution to a programming problem so now you have seen an alternate way to keep track of the number of any kind of agent.
Another Approach to Troubleshooting:

Make a quick check on how many Pellets are in the World:

Click on the gear button on the upper right side of the AgentCubes Online window and select “Show simulation Properties”. This window will appear:

![Simulation Properties Window]

The correct number of Pellets will not appear in this window until you have single-stepped (click on the black triangle next to the stop and go buttons) or briefly run the game. If your programming is correct, the value of Pellets will decrease by 1 each time PacMan eats (erases) a Pellet. When the value of Pellets is equal to 0, PacMan should win the game.

More detailed troubleshooting:
To determine what is happening in your game, it is helpful to look at how the simulation property changes over time. Add the `plot to window` action to the rule in the Controller’s `while running` method.
Fill it out as it appears below:

In the **plot to window** action, you must name the simulation property to be plotted (Pellets), name the window where it will appear (Pellets Plot), say what it represents (number of pellets) and pick the color of the line that will appear on the graph. **Note that you must put “@” before the Pellets in the plot to window box because you are checking the value of the simulation property Pellets!**

The Pellets Plot window will appear as soon as the run button is clicked. Move the Pellets Plot window somewhere where you can watch it while you run the game. In this window, you will see a graph that shows you what’s happening ‘behind the scenes’ while you play the game.

This information will help you determine where a mistake may be. For example, if the number of pellets never goes above 0, there is a problem with the method Count or the broadcast. If the number of pellets goes to zero but the game doesn’t end, there is a problem with the game ending rule in the Controller.
End of Unit Review Sheet – PacMan

(page 22 of the standard packet, page 26 of the alternative packet)

A) The main computational thinking patterns we reviewed were:
   1) **User Control**: intentionally moving an agent.
      a. Using keyboard keys to move an agent.
      b. Example is moving the PacMan.
   2) **Absorb**: deleting agents on the screen.
      a. Use the “Erase” action in AgentCubes Online.
      b. Examples are erasing the pellets.
   3) **Collision**: when 2 agents collide (run into each other).
      a. Use the “See” condition
      b. Use the “Stacked” condition, OR
      c. Use the “Next to” condition.
      d. Examples are the eating pellets and losing the game when the ghosts touch the PacMan.

B) The main NEW computational thinking patterns we learned were:
   1) **Diffusion**: spreading the scent (smell) of an agent across a medium (like the background). We use an agent attribute (S for smell) on the agent which should be chased, and we diffuse the smell by setting the attribute on the background using the average of the 4 smells around it,

      \[ S = 0.25 \times (S_{left}+S_{right}+S_{up}+S_{down}) \]

   2) **Hill Climbing**: following the highest value of the scent S. It only works if there is diffusion done with it, so they go hand in hand. Example is the method we created in the Ghost to move towards the agent next to him with the highest value of the scent “S”.

   3) **Broadcasting**: is when we “shout out” to all agents of a certain type requesting them to execute a specific method.
      a. Use the “broadcast” action in AgentCubes Online.
      b. Example is the broadcast by the Controller of the method “Count” to the pellets so they will count themselves.

C) Other concepts we covered in AgentCubes Online are:
   1) Troubleshooting the simulation, and considering rule order.
   2) Using sounds and messages in the game.
   3) Timing our actions using the “Once every” condition.
Student Handout 4a:

Challenge 1: PacMan Changes Direction

(page 23 of the standard packet, page 27 of the alternative packet)

Before your start this challenge:

You must have a complete basic PacMan game with a PacMan who wins if he eats all the pellets and Ghosts who either move randomly or chase the PacMan. The PacMan loses if a Ghost gets too close. The world should have walls that the Ghost and PacMan cannot cross.

Description of the Challenge:

PacMan will turn in the direction he’s heading.

Keep in mind there are multiple ways to solve this. Before reading ahead, try solving this challenge your own way. Do you need new/different rules? New agents/shapes?

Option 1: Each PacMan follows the same rules so you need 3 new shapes instead of a new agent

Steps:

- Select PacMan by clicking on him, then click on +Shape
- Clear the picture and draw PacMan facing a different direction.
- Use the change action with a dot in the middle because the means “change me to” so the agent is able to change its shape.

Option 2: Instead of making new shapes, use the “rotate to” command

Steps:

- Edit the move behavior of PacMan to include a “rotate to” command
- The first of the three numbers in “rotate to” is the rotation you want, a rotation of 180 degrees will cause PacMan to turn in the opposite direction.

Once you are done, TEST your program to confirm that the PacMan’s shape changes when he changes directions as he moves.
Student Handout 4b:

Challenge 2: PacMan Moves Continuously

(page 24 of the standard packet, page 28 of the alternative packet)

Before your start this challenge:

You must have a complete basic PacMan game with a PacMan who wins if he eats all the pellets and Ghosts who either move randomly or chase the PacMan. The PacMan loses if a Ghost gets too close. The world should have walls that the Ghost and PacMan cannot cross.

You must have 4 different shapes for the PacMan so that he faces the direction he heads.

Description of the Challenge:

PacMan will continuously move in the direction he’s heading.

This challenge gets you started, but won’t give you all the code. Review the code below: It says, when the right arrow is pressed AND I do not see a wall to the right, change to the right-facing depiction. Once every 0.2 second, make me (the PacMan) do “move continuously”.

When the move continuously method is called, the PacMan does the following:
If I see myself heading right AND I do not see a wall in the right direction, I will move right.

The effect of the rule in move continuously is to make PacMan keep moving whichever way he is facing as long as there are no walls in the way.
There is still much to code:

**Step 1:**
Create code for all the other directions.

**Step 2:**
*Test your program.* (Hint: be sure your PacMan still leaves his scent everywhere.)
*Click* on the PacMan with the big arrow tool to select him and run the program.

Use the colors to decide which rules are true or false. In this case, the first rule is red, which means the Right arrow was not pressed or a wall was in the way.

The next rule is green, which means every 0.2 seconds, the PacMan is being told to do MoveDirection.

The method MoveDirection is green, which means that either or both conditions are true. The PacMan does see his right-facing shape AND does not see a wall, making the rule TRUE, so PacMan will move one step to the right.
Student Handout 4c:

Challenge 3: Power Pellet

(page 26 of the standard packet, page 30 of the alternative packet)

Before your start this challenge:

You must have a complete basic PacMan game with a PacMan who wins if he eats all the pellets and Ghosts who either move randomly or chase the PacMan. The PacMan loses if a Ghost gets too close. The world should have walls that the Ghost and PacMan cannot cross.

You must have different depictions of the PacMan so that he faces the direction he heads, and he must move continuously.

Description of the Challenge:

- Power Pellets are added to the world.
- Power Pellets provide PacMan with the temporary ability to eat the enemies. The enemies turn deep blue, and reverse direction.

This challenge gets you started, but won’t give you all the code.

To help you think this through…

- You will need a new agent (Power Pellet)
- Do you need a new agent or a new shape for the blue ghost?
- When the ghost chases the PacMan, PacMan has a scent of 1000. What happens if he has a scent of -1000? How can you set that new scent?
- How can you limit the time that PacMan’s scent is -1000? Could you create a timer agent that starts counting when it receives a message from PacMan that he ate a Power Pellet? The timer agent should send a message back to PacMan when it is done counting and it’s time for PacMan’s scent to return to 1000.
- Hint: Use the hill climbing action rather than all the code for sniffing.
Student Handout 4d:

Challenge 4: Next Level

(page 27 of the standard packet, page 31 of the alternative packet)

Before your start this challenge:

You must have a complete basic PacMan game with a PacMan who wins if he eats all the pellets and Ghosts who either move randomly or chase the PacMan. The PacMan loses if a Ghost gets too close. The world should have walls that the Ghost and PacMan cannot cross.

You must have different depictions of the PacMan so that he faces the direction he heads, and he must move continuously.

Description of the Challenge:

- When the game ends, a new level appears, even harder than before!

This challenge gets you started, but won’t give you all the code.

To help you think this through…

- Do you need a new agent? A new world?
- When would a new level appear?
- What code needs to change to make the new level appear?

You might have a rule like this:

```
if test []Pellets = 0
  play sound Hallelujah.mp3
  show message PacMan won!
  stop simulation
```

How could you use this condition and this action to let the player move from a world named “Level 1” to a world named “Level 2”?

Very Important Note: Add another rule that stops the simulation if the player has won Level 2 so the game ends!
Appendix 1: Guidance on Ghost’s Random Movement

Making the ghosts move randomly on both pellets and ground is a challenge and your students will come up with many different solutions that do not work.

Your students may make rules that look like these two examples:

![Diagram of ghost behavior]

What happens with the rules above if there are pellets on the ground? Can the ghost move?

![Diagram of ghost behavior]

What happens in this case if the ghost is on the ground? Can the ghost move?

It helps to understand how timer events work. A “once every” condition can be interpreted like this: “Has this amount of time passed since the last time this condition was true?” Once the set amount of time has passed, the rule will remain true until the “then” condition (move random in this case) has been preformed. Once that happens, the condition is no longer true and it goes back to the start of the method. This means it will never get to the second “once every” condition.

**Both of these sets of rules will work correctly and allow Pac-Man to move on pellets and ground if the once-every condition has a different time for the second rule**
PacMan

ISTE Standards\(^5\) specific to the implementation of PacMan (Denoted with (\(\star\)))

Creativity and Innovation

Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students:

Apply existing knowledge to generate new ideas, products, or processes:

- Design and develop games
  - Design and develop computational science models
- Create original works as a means of personal or group expression.
  - Design original games
  - Model your local environment, e.g., ecology, economy
- Use models and simulations to explore complete systems and issues.
  - Model scientific phenomena, e.g., predator / prey models
  - Create visualizations
- Identify trends and forecast possibilities.
  - Build predictive computational science models, e.g., how the pine beetle destroys the Colorado pine forest
  - Build live feeds to scientific web pages (e.g., weather information), process and visualize changing information

Communication and Collaboration

Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students:

Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media:

- Students work in teams to build and publish their simulations as web pages containing java applets.

Communicate information and ideas effectively to multiple audiences using a variety of media and formats.

- Effectively combine interactive simulations, text, images in web pages

Develop cultural understanding and global awareness by engaging with learners of other cultures.

- Students and teachers from the four culturally diverse regions interact with each other

Contribute to project teams to produce original works or solve problems.

- Define project roles and work collaboratively to produce games and simulations

Research and Information Fluency

\(^5\) ISTE Standards for Students (ISTE Standards\(\star\)S) are the “standards for evaluating the skills and knowledge students need to learn effectively and live productively in an increasingly global and digital world.”  http://www.iste.org/standards/standards-for-students
Students apply digital tools to gather, evaluate, and use information. Students:

**Plan strategies to guide inquiry.**
- Explore web sites and identify interesting connections

**Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.**
- Find relevant related web-based information, compute derivate information

**Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.**
- Understand validity of information, e.g. Scientific journal information vs. Personal blogs

**Process data and report results.**
- Write programs to access numerical information, define functions to process data and create output based on voice or plotting to represent data.

**Critical Thinking, Problem Solving, and Decision Making**

Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. Students:

**Identify and define authentic problems and significant questions for investigation.**
- Define research questions and explore approach of exploration

**Plan and manage activities to develop a solution or complete a project.**
- Outline sequence of exploratory steps
- Experience complete bottom-up and top-down design processes
- Employ algorithmic thinking for creating programs to solve problems

**Collect and analyze data to identify solutions and/or make informed decisions.**
- Collect data as time series, e.g., collect group size of predator and prey, export time series to excel, explore various types of graph representations, e.g., x(t), y(t) or scatter y=f(x)

**Use multiple processes and diverse perspectives to explore alternative solutions.**
- Experience and understand design trade-offs, e.g. Bottom-up vs. Top-down

**Digital Citizenship**

Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior. Students:

**Advocate and practice safe, legal, and responsible use of information and technology.**
- Learn how to use tools to locate resources, e.g., images with Google image search, but understand copyright issues

**Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.**
- Stay in the flow, where design challenges match design skills
- Experience success through scaffolded game design activities
- Mentor other students
Demonstrate personal responsibility for lifelong learning.

- Explore options of going beyond expected learning goals

Exhibit leadership for digital citizenship.

- In a collaborative setting become a responsible producer of content for diverse audiences

Technology Operations and Concepts

Students demonstrate a sound understanding of technology concepts, systems, and operations. Students:

Understand and use technology systems.

- Know how to organize files and folders, launch and use applications on various platforms

Select and use applications effectively and productively.

- Know how to orchestrate a set of applications to achieve goals, e.g., make game and simulations using Photoshop (art), AgentCubes Online (programming), and Excel (data analysis).

Troubleshoot systems and applications.

- Debug games and simulations that are not working

Transfer current knowledge to learning of new technologies.

- Reflect on fundamental skills at conceptual level. Explore different tools to achieve similar objectives.