Chapter 3: Input / Output

3.0.1 Objective

Modern computers use a rich variety of forms of input and output. In this unit, students will explore output of images, text, speech, and music, and they will explore input of mouse clicks, buttons, text, voice, and keypresses. Although programs that combine input and output can be created with just a few lines of code, these simple programs can be among the most interesting and engaging for students. Any form of input can be attached to any form of output, so creating connections between input and output provides a large range of creative possibility.

3.0.2 Topic Outline

3.0.3 Key terms

Input	Output
Human Computer Interaction (HCI)	Event Objext
Event Handler	Event Binding Function
Say, Play	Await
Spiral assignment	Assignment statements
Variables	

3.0.4 Key Concepts

Computers are most interesting when used to interact with the world.

- **Input** brings data into the computer, e.g., when you type on a keyboard.
- **Output** sends data out of the computer, e.g., when you see things on the screen.

Together, input and output are sometimes called I/O. There are many types of I/O including human interfaces, network interfaces, storage interfaces, and robotic interfaces. There is a lot of commonality in how a computer program deals with all these types of input and output, regardless of whether the interaction is with a person, a file, or some other device. User can learn important I/O techniques just by learning how to create user interfaces.

Common Forms of Human Computer Interaction

This section focuses on **human-computer interaction (HCI)**. When creating a user interface in a Web application, programmers deal mainly with keyboard and mouse input, and with screen and audio output. Here are some examples:

	Input	**Output**
Graphical	Mouse, keypress	Graphics
Text-Oriented	Keyboard input	HTML
Audio	Microphone	Music, Speech

An Overview of I/O Concepts to Teach

Introduction to input and output:

- Output of graphical images, as seen in Chapter 2
- Simple input of mouse clicks
- Combining input and output

Expanding to different types of input and output:

- How to output text
- How to output speech, and music
- How to input from keys and buttons
- How to input text and speech

Special input strategies:

- Using CoffeeScript “await” to wait for input
- Using “pressed” to poll for input

Events for Mouse Click Input

In a graphical environment, the simplest way to collect input is to listen to **events**. An event is an object created by the system that represents a single unit of input. For example, every time the mouse is clicked, an event object is created representing the click. The event object has properties representing details of the input such as the position, time, and which mouse button was clicked.

Event e

`e.type = 'click'`	The kind of event
`e.x = -195`	X position of click
`e.y = 40`	Y position of click
`e.which = 1`	Which mouse button
`e.timestamp = 1454775914487`	Number representing the time of the click.

An event object has properties representing details of the input, such as its position and time, and which button was used. Not all properties of the click event are shown here.

Clicking the mouse creates an invisible event object.

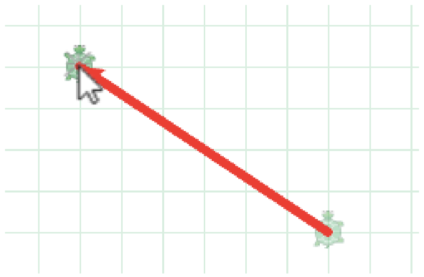
Event objects are created by the system whenever user input occurs. A program can respond to events by creating event handlers, explained next.

Creating Event Handlers

An event handler is a piece of code that runs to process an input event. It looks something like this:

```
click (e) ->
  moveto e.x, e.y
```

An event handler to process a click event. Each time a mouse click occurs, the handler runs and moves the turtle to the location of the click.



There are three key parts of the code in the set up for an event handler.

The `(e)` is the **event object** parameter. When the input happens, the event object (containing the location of the click on the screen) is made available in the variable e. The variable name can be chosen to be any convenient name. It is conventional to use the name “e”, or “event” for an event object.

All together, the `(e) -> moveto e.x, e.y` is the **event handler** function, which is the code to run when the event happens. Any number of lines of code can be indented after the arrow, and they will all be part of the same event handler. (An event handler happens to be a **function**, which we will talk more about in Chapter 5.)

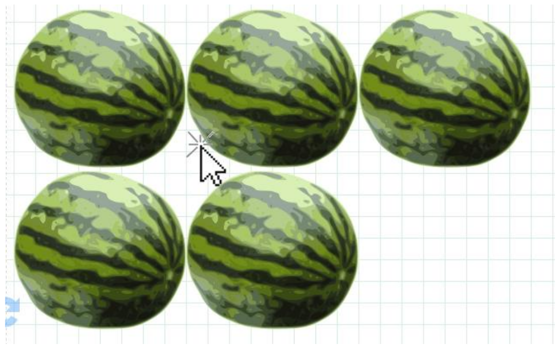
The `click` command is an **event binding function** that means “listen to clicks”. It is a command that connects the event handler to the system so that the handler is triggered when there is a click.

Combining Input and Output

The magic of input and output lies in creating new effects by combining them. For example, a new image can be created for each click with this:

```
click (e) ->
  img 't-watermelon'
```

Combining input and output by creating a new image within a click event handler. A watermelon is drawn for each click.



As students learn different types of input and output, it is helpful to have them try combining input and output in different ways. Have students try the following:

`click (e) ->`
`  w = img 't-watermelon'`
`  w.moveto e.x, e.y`
	In addition to making an image, move it to the clicked location.

`w = img 't-watermelon'`
`click (e) ->`
`  w.moveto e.x, e.y`
	Move only a single watermelon image instead of making a new one for each click.

`pen purple`
`click (e) ->`
	Draw a line between clicks.

```
moveto e.x, e.y
```

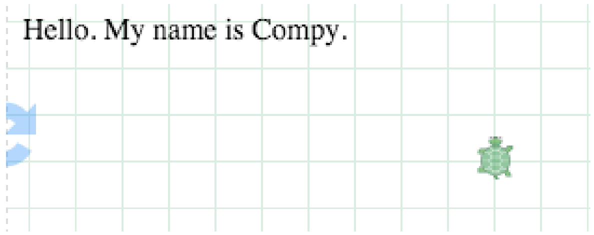
Students can create a simple drawing program using just click events. They can do even more if they combine different kinds of input and output.

Output of Text

To write text output on the screen, use the `write` command like this:

```
write 'Hello.  My name is Compy.'
```

Writing a line of text output. The write command writes text from top to bottom, not at the the turtle.

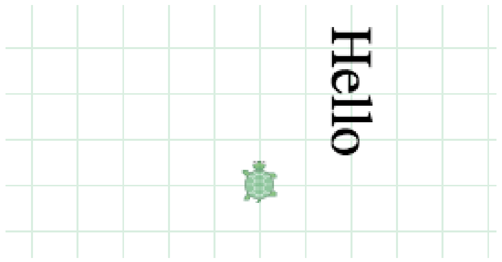

Hello. My name is Compy.

When text is written to the screen using “write”, it appears from top to bottom on the screen, under all the written text so far (not, for example, where the turtle is). The “img” command also puts new images at the end of all written text and images so far.

Just like img, it is possible to use a variable to remember a text object and move it on the screen:

```
t = write 'Hello'
t.moveto 50, 100
t.rt 180
t.grow 2
```

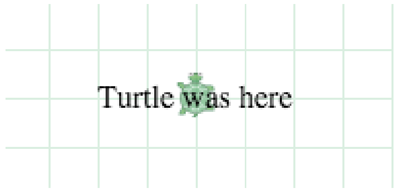
By using a variable with written text, text can be moved, turned, and grown.



To create text on the screen at the location of the turtle, the “label” command can be used:

```
label 'Turtle was here'
```

The label command makes text at the location of the turtle.



Labels can also be moved in the same way as text with write and images, by using a variable.

Output of Speech and Music

The screen is not the only output device on a computer! The computer can also output using audio. There are two interesting ways to do this: using speech or using tones.

The `say` command utters speech audibly.

```
say 'Hello. My name is compy.'
```

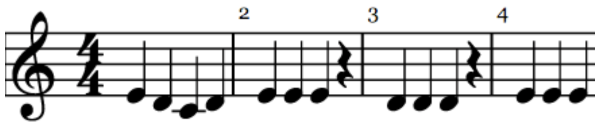
The say command utters speech aloud.

To hear a program that uses speech, the browser needs to support speech synthesis. Chrome, Safari, and Opera do, and browser support for speech standards may increase over time. The webpage http://caniuse.com/#feat=speech-synthesis lists current browser versions that support speech.

The `play` command plays a song using ABC notation, which represents each musical note with the letter that musicians use for the note.

```
play 'EDCDEEEzDDDzEEE'
```

The play command uses ABC notation to play musical notes.



In ABC notation, the letters A-G are used for notes. Uppercase is an octave higher, and the letter z rests silently for a beat.

There are many other things that can be done with ABC notation (which you can read about by searching for “ABC notation” on Google). For example, put a number “2” or fraction “1/2" after a note to change the number of beats of that note, or put a “^” or “_” before a note to make it “sharp” or “flat”, or a comma after a note to make it an octave lower.

The play command will sequence notes and wait its turn before beginning a song, but sometimes in an interactive program, it is useful to play a note right away (without sequencing). To play a tone right away without sequencing, use the “tone” command:

```
tone 'C'
```

Use tone to make a sound immediately.

Together, these are all the tools needed to make the computer say something or play a song or a tone or write or utter a word when you click the mouse. Have students experiment with the different types of output to create different types of interactions. Students should experiment to understand the difference in timing between using “`play`” and “`tone`” when responding to multiple mouse clicks.

Input from Keyboard and Buttons

The mouse button is only one of the buttons a computer has: a typical computer will have another 100 or so buttons on a keyboard!

An event handler can be used to collect input from those buttons using two other event binding functions: `keydown` and `keyup`.

```
keydown 'A', ->
  tone 'C'
```

Pressing the A on the keyboard sounds a C.

The program above will sound the C tone whenever the user presses down on the “A” key.

The comma after the key name is necessary. The comma is used because `keydown` is an event binding function that is using two arguments instead of one: the first argument is the name of the key, and the second argument is the event handler. Like any other command with two arguments, a comma must be used between the arguments.

There is also a `keyup` event binding function. For example, to silence the C note when the user lets go of the key, use this trick for sounding a zero-duration C when you release the A key:

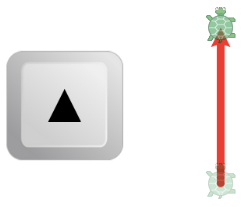
```
keydown 'A', ->
  tone 'C', 0
```

Releasing the A on the keyboard silences the C.

Many keydown and keyup event handlers can be combined create a whole piano or to create other effects. For example, it is possible to create event handlers to attach turtle movements to specific keys and make a system for steering the turtle around. Notice that the letter keys have obvious names, but there are also names for the arrow keys: you can listen to the “up” arrow by saying keydown 'up', and similarly for “down”, “left”, and “right”.

```
keydown 'up', ->
  fd 100
```

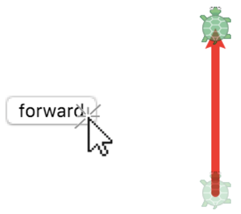
The up arrow key moves the turtle forward.



An alternative to using physical keyboard keys is to use on-screen buttons. The “button” command is used for this:

```
button 'forward', ->
  fd 100
```

An on-screen button labelled “forward” moves the turtle forward.



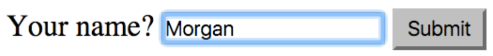
The advantage of on-screen buttons is that the user can see exactly what controls are available. With good labels, they are self-explanatory. The disadvantage is that they take space on the screen.

Input of Text and Speech

When collecting text input from a user, listening to a single keypress at a time can be done, but it is very inconvenient! That is why user interfaces use text input elements for entering text. The input element is a box that shows text, and when it has focus, all keypresses automatically turn into text in the box.

To use a text input box in Pencil Code, use the read command, like this:

```
read 'Your name?', (n) ->
  write 'Hello, ' + n
```



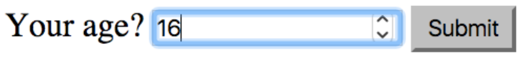
The handler is triggered after text is entered and submitted.

As with click or button or keydown, the read command calls an event handler after the user has finished providing input. There are a few differences between read and click:

- Instead of waiting for a single small action, read waits for a whole series of keystrokes and then finishes when the user presses “Enter” (or clicks submit).
- The event handler for `read` is called just once. After the input, the input box goes away.
- Instead of binding the variable to an event object that has properties like x and y, read sets it to the text value that was input (n in the example above).

To enter a number, consider the special variant `readnum`, which constrains the input to just digits.

```
readnum 'Your age?', (n) ->
  write 'Next year you will be ' + (n + 1)
```

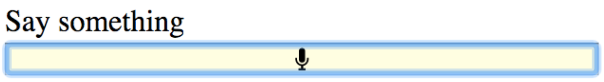


Your age? 16

readnum constrains input to a number.

A keyboard is not the only way to enter text. Another option is to use voice input, which can be done using “listen”. That function works just like “read”:

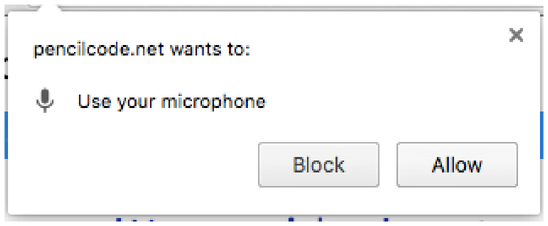
```
listen 'Say something', (t) ->
  say 'You said: ' + t
```



Say something

listen accepts spoken voice input.

A few tips for working with voice: Currently voice recognition and speech synthesis work only on Chrome. Before a webpage attempts turns on the microphone on Chrome, it must obtain the user’s permission. If using the https (secure) version of Pencil Code, Chrome will remember the permission after it is given first time so it does not need to ask every time.



pencilcode.net wants to:

Use your microphone

When a page listens to the microphone, the browser asks for permission.
If the page is loaded over https, the permission is remembered.

Using CoffeeScript await to Wait for Input

Sometimes a program needs to read a sequence of inputs. To do this, chain the event binding functions inside one another like this:

```
readnum 'Right triangle side a?', (a) ->
  readnum 'Right triangle side b?', (b) ->
    c = sqrt(a*a + b*b)
    write 'The hypotenuse is', c
```

```
Right triangle side a? 12
Right triangle side b? 5
The hypotenuse is 13
```

Using a sequence of input by chaining event handlers.

This nesting makes the program look more complicated than it is, and make it difficult to use a loop.

The version of CoffeeScript used in Pencil Code has a pair of keywords “`await`” and “`defer`” that can help in this situation by putting a program on hold while waiting for an event to occur. You put the word “`await`” before the command that you want to pause, and “`defer`” in the place of an event handler along with any variables that would have been event handler parameters:

```
await readnum 'Right triangle side a?', defer a
await readnum 'Right triangle side b?', defer b
c = sqrt(a*a + b*b)
write 'The hypotenuse is', c
```

Await and defer have a subtle relationship with function calls, so before putting await inside a user-defined function, find understand the Web pages about “Iced CofeeScript” (if using await inside a function, that function should also return its results using callbacks).

However, await is very straightforward and useful when used together with loops. Here is an example:

```
await readnum 'How many numbers to average?', defer count
total = 0
for j in [1..count]
  await readnum 'Enter #' + j, defer val
  total += val
write 'The total is ' + total
write 'The average is ' + (total / count)
```

This style of code is called “blocking i/o”, because the program blocks (stops) its progress while waiting for an input or output to occur. Blocking i/o is the traditional way to teach Python or C input/output, but it is very different from the way UI events are typically handled in JavaScript or Java GUIs, where input is done using event handlers. Iced CoffeeScript’s `await` allows teaching both styles in the same system, and even in the same program.

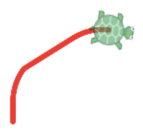
The `await` keyword is so useful that a version of it is on track to be added to a future version of the JavaScript standard. However, it is not in the language right now, so you cannot use `await` in JavaScript today. Instead, you must use function definitions (see Chapter 5) to achieve similar effects.

Polling Keyboard State Using pressed

So far we have seen two styles of input: “event handling”, and “blocking i/o.” A third style of input, called **polling**, is often used in video games and real-time systems such as robots and you can also try it with Pencil Code. A program using polling repeatedly checks the input state (of the keyboard) by asking a question such as “is the key pressed down right now?”

Here is how Pencil Code does polling (usually in combination with the “forever” command).

```
forever ->
  if pressed 'W'
    fd 2
  if pressed 'D'
    rt 2
```



Inside a forever block, the function pressed can be used to poll the keyboard state.

The “pressed” command is the polling command. It is true if a key is pressed and it is false if the key is not pressed. The “if” can be used decide whether to take an action based on the state of a key. With “pressed,” it is even possible to support “chording”, that is, making a program that responds to two keys pressed at the same time. Students can experiment with this effect in the program above.

Polling is an advanced technique and there are several subtleties for getting it to work correctly that are handled by the “forever” command. A “forever” loop differs from a traditional loop in several ways.

Inside a “forever” loop, the speed of turtles is automatically set to Infinity to avoid animation delays. Also, a “forever” loop will also automatically put a short delay between each repetition so that you can see the effects of the repetition over time. You can change the framerate of the “forever” loop by adding an extra number argument. For example, “forever 10” will do 10 frames per second.

```
forever 10, ->
  if pressed 'space'
    fd 1
  rt 1
```

The frequency of a forever block, adjusted to 10 repetitions per second.

Combining Ideas

This unit on input and output covers a lot of powerful concepts, but the real power comes from finding creative new ways to combine input and output. By combining graphics, text, and audio, students can create applications such as calculators, games, conversational assistants, interactive drawing programs, or musical instruments.

Each application may require a particular i/o model. The most common models are: event-based i/o, blocking i/o, and polling. Sometimes the same application can be built in a different way using a different i/o model so it is worth having students experiment with more than one model to learn how they work.

3.1.1 Suggested Timeline: 1 55-minute class period

Instructional Day	Topic
1 Days	Lesson Plan I: Text and Sound Blocks
1 Day	Lesson Plan II: Use of Buttons and Click (e) controls to show input
1 Day	Lesson Plan III- Demonstrate the use of the /img bot
2 Day	Lesson Plan IV Lab Activity – choose between a shape bot or paint bot

3.1.2 Standards

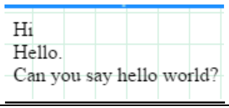
CSTA Standards	CSTA Strand	CSTA Learning Objectives Covered
Level 3 A (Grades 9 – 12)	Computational Thinking (CT)	Describe how computation shares features with art and music by translating human intention into an artifact.
Level 3 A (Grades 9 – 12)	Computers and Communication Devices (CD)	Describe the principal components of computer organization (e.g., input, output, processing, and storage).
Level 3 A (Grades 9 – 12)	CD	Compare various forms of input and output.

3.1.3 Lesson Plan I

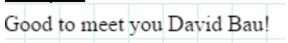
This lesson focuses on using the Text, Sound and Control block palettes. Click on the Text, Sound and Operators block to show students that input/output statement commands are located under these palettes. Read and type the code as shown below and demonstrate the output to the students.

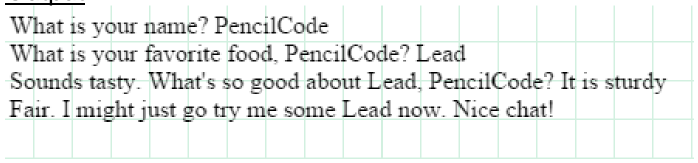
Note: Make sure you are in block mode. Type in the code (switch to block-mode if needed) and click the play arrow to demonstrate the results.

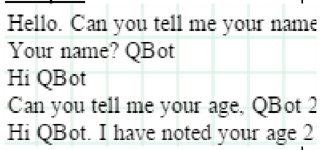
Content details	Teaching Suggestions	Time

Demonstrate `write` and `say` (Text & Sound block).
`Write_Say`
`write 'Hi'`
`write 'Hello.'`
`write 'Can you say hello world?'`
	These are the output statements.
	
	Hi
	Hello.
	Can you say hello world?
		Demonstration 10 minutes

Content details	Teaching Suggestions	Time
`say 'Hello World!'`	Type in the code and click the play arrow to demonstrate the results.	

Displaying expressions
`name = 'David Bau'`
`write 'Good to meet you ' + name`
Output

Good to meet you David Bau!
	Show how `write` can show the value of a variable or an expression.	Demonstration
		10 minutes

The question bot is a simple program that asks questions and displays responses in an intelligent manner.
 	
Code:
`# questionBot`
`# short interview with await..defer`
 	
`await read 'What is your name?', defer name`
`await read ('What is your favorite food, ' + name) + '?', defer food`
`await read ("Sounds tasty. What's so good about " + food) + ', ' + name + '?', defer response`
`write 'Fair. I might just go try me some ' + food + 'now. Nice chat!'`
Output

What is your name? PencilCode
What is your favorite food, PencilCode? Lead
Sounds tasty. What's so good about Lead, PencilCode? It is sturdy
Fair. I might just go try me some Lead now. Nice chat!
	Input Statements: Demonstrate `Await - Read`, using Question Bot (`Text` Block)
	
	`Await` waits till an input is received. It then stores the input to the variable declared next to defer.
		Demonstration
		15 minutes

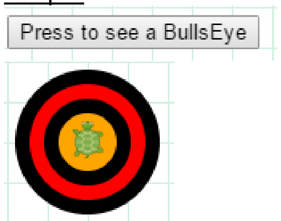
Code:
`# Question Bot using numbers`
`write 'Hello. Can you tell me your name please?'`
`await read 'Your name?', defer name`
`write 'Hi '+ name`
`await readnum 'Can you tell me your age, ' + name, defer age`
`write 'Hi ' + (name + ('.  I have noted your age '+ age))`
	Demonstrate `Await – ReadNum` using Question Bot (`Text` Block).
	Output
	
	Hello. Can you tell me your name
	Your name? QBot
	Hi QBot
	Can you tell me your age, QBot 2
	Hi QBot. I have noted your age 2
		Demonstration
		15 minutes

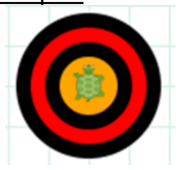
Students can now work on their version of Question Bot.	Encourage students to express their own individuality and creativity and experiment with using “Say” in places where “Write” is used. What happens?	Student Practice 15 minutes
Look at exercises	Using the `Art, Move, Text` and `Sound` block	Student Practice 15 minutes

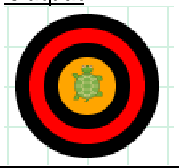
3.1.4 Lesson Plan II

This lesson discusses the use of Buttons: the use of button clicks as input.
Note: Make sure you are in block mode. Type in the code (switch to block-mode if needed) and click the play arrow to demonstrate the results.

Content details	Teaching Suggestions	Time

<u>Code</u>
`button 'Press to see a BullsEye', ->`
`  x = 18`
`  dot black, x * 5`
`  dot red, x * 4`
`  dot black, x * 3`
`  dot orange, x * 2`
	Demonstrate `Button` (`'Click'`)
	The `Button` option lets the user label the button and runs the code that is within the block.
	<u>Output</u>
	
		Demonstration
		20 minutes

<u>Code:</u>
`keydown 'a', ->`
`  x = 18`
`  dot black, x * 5`
`  dot red, x * 4`
`  dot black, x * 3`
`  dot orange, x * 2`
	Demonstrate Keydown
	The `Keydown` waits for the 'a 'key pressed to execute the code within the block.
	<u>Output:</u>
		

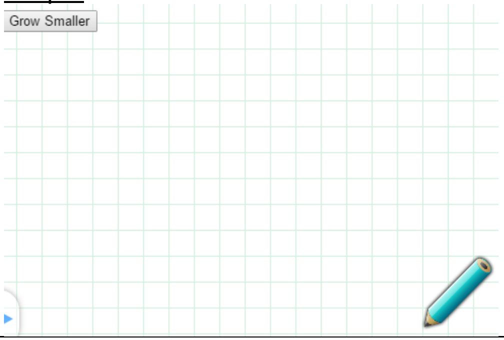
<u>Code:</u>
`click (e) ->`
`  moveto e.x, e.y`
`  x = 18`
`  dot black, x * 5`
`  dot red, x * 4`
`  dot black, x * 3`
`  dot orange, x * 2`
	Demonstrate Click
	The click will wait for a mouse click and then execute the code within the block.
	The e variable represents the click event, so
	`moveto e.x, e.y`
	moves to the location of the click.
	<u>Output</u>
		

Finish the lab exercise that was started the pervious class period..		Student Practice: Use the remainder of class period and homework if needed.

3.1.5 Lesson Plan III

This lesson plan introduces the Buttons and the Click (e) capability along with `wear` and `img` blocks which display images from the internet. The wear and img blocks are available under the Art panel.
Note: Make sure you are in block mode. Type in the code (switch to block-mode if needed) and click the play arrow to demonstrate the results.

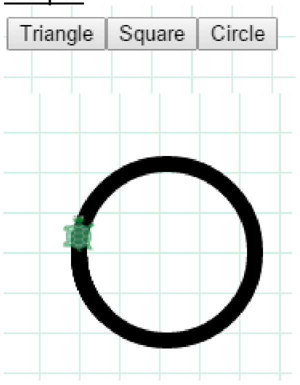
Content details	Teaching Suggestions	Time

Code:
`wear 't-pencil'`
`button 'Grow Smaller', ->`
`  jumpxy 30, 20`
`  grow 0.5`
`button 'Grow Larger', ->`
`  grow 2.0`
 	
Output

	Demonstrate how the `wear` block works. Open the ImgBot program.
	
	Point out the use of `Button` and `Click` (e) from the previous lesson plans.
	
	Explain how `wear` and `img` work (refer to key concepts if necessary).
	Substitute other values for pencil and show the kinds of images that result.
	
	Encourage students to play with the `wear` and `grow` blocks.
		Demonstration: 20 minutes
		
		Student activity: 25 minutes.

3.1.6 Lesson Plan IV

This lesson plan provides instructions for designing the Shape Bot. Students Design a simple program that draws geometric shapes such as a square, triangle, circle, etc. The program first asks the user for a shape. It asks from the user to provide details such the number of sides, length of sides, and the radius of the circle, etc.

Content details	Teaching Suggestions	Time

Code:
`speed 100`
`pen black, 10`
`button 'Triangle', ->`
`  await read 'How long are the sides?', defer side`
`  cs()`
`  fd side`
`  rt 120`
`  fd side`
`  rt 120`
`  fd side`
`  rt 120`
`button 'Square', ->`
`  cs()`
`  await read 'How long are the sides?', defer side`
`  fd side`
`  rt 90`
`  fd side`
`  rt 90`
`  fd side`
`  rt 90`
`  fd side`
`  rt 90`
`button 'Circle', ->`
`  cs()`
`  await read 'How long is the radius', defer radius`
`  rt 360, radius`
`  fd 10`
	Give the lab program to the students. Encourage them to experiment and improve the design of the program. After students have worked on it pull up the Shapes Bot program and start walking the students through the program. Encourage students to come up and demonstrate their work.
	Output
	
		Student activity 55 minutes.
		
		Demonstration 20 minutes

Encourage students to explore and understand their inclinations and strengths in programming by giving various assignments to accomplish the same purpose. For example, consider a simulation of paint splatter drawn as a collection of colored dots. This can be called the Paint Splatter Bot.		

3.2 Resources

Important Links:

http://gym.pencilcode.net

Book: book.pencilcode.net