Nested Structures

Containers are objects that store other objects. For example, `list` stores a sequence of objects, and `dict` stores a mapping of objects to objects. Containers can also hold other containers, which makes it possible to represent any type (or shape) of data.

Content Learning Objectives

After completing this activity, students should be able to:

- Explain how rows and columns of data can be stored in lists.
- Write nested for loops to iterate data and compute functions.
- Navigate a complex data structure with dictionaries and lists.

Process Skill Goals

During the activity, students should make progress toward:

- Developing algorithms that loop through lists to compute a result. (Problem Solving)

Model 1 Lists of Lists

Connect Four (® Hasbro, Inc.) is a two-player game in which the players take turns dropping colored discs into a six-row by seven-column grid. The objective of the game is to be the first player to form a horizontal, vertical, or diagonal line of four of one's own discs. (paraphrased from https://en.wikipedia.org/wiki/Connect_Four)


```
# current state of the game
grid = [
    [' ', ' ', ' ', ' ', ' ', ' ', ' '],
    [' ', ' ', ' ', ' ', ' ', ' ', ' '],
    ['Y', ' ', ' ', ' ', 'Y', 'Y', ' '],
    ['R', ' ', ' ', 'Y', 'R', 'R', ' '],
    ['R', 'R', 'Y', 'R', 'Y', 'R', ' '],
    ['R', 'Y', 'R', 'Y', 'Y', 'Y', 'R'],
]
```

Enter the `grid` code above into a Python Shell, and run each line of the table below. If the output is longer than one line, summarize it with a few words.

Python code	Shell output
`print(grid)`	
`print(grid[5])`	
`print(grid[5][0])`	
`type(grid)`	
`type(grid[5])`	
`type(grid[5][0])`	
`len(grid)`	
`len(grid[5])`	
`len(grid[5][0])`	
`import pprint`	
`help(pprint)`	
`pprint.pprint(grid)`	
`for item in grid:` `  print(item)`	
`for i in range(len(grid)):` `  print(grid[i])`	

Questions (15 min) Start time: _____

1. What does `grid` look like when you first `print` it? (How is the output different from the original format shown in Model 1?)

2. What does `grid` look like when you use `pprint` instead? Explain what `pprint` means.

3. When viewed as a rectangle, how many "rows" and "columns" does `grid` have?

4. What type of object is `grid`? What type of objects does it contain?

5. What type of object is `grid[5]`? What type of objects does it contain?

6. In the expression `grid[5][0]`, which index corresponds to the row, and which index corresponds to the column?

7. Is `grid` a list of rows or a list of columns? Justify your answer.

8. Describe how to append one more row to `grid`.

9. What is necessary to append a "column" to `grid`?

Model 2 Nested `for` Loops

Example A
We typically use a `for` loop to examine the contents of a list:

```
1 groceries = ["Apples", "Milk", "Flour", "Chips"]
2 for item in groceries:
3     print("Don't forget the", item)
```

Example B
If a list contains another list, we need a `for` loop that contains another `for` loop. For example, to count the "spaces" in the `grid` from Model 1:

```
4 count = 0
5 for row in grid:  # outer loop
6     print("row =", row)
7     for cell in row:  # inner loop
8         print("cell =", cell)
9         if cell == ' ':
10            count += 1
11 print(count, "spaces remaining")
```

Questions (15 min) Start time: _____

10. As a team, discuss the two examples from Model 2. Predict how many times each of the following lines will execute. Then run the code and check your answers based on the output.

a) How many times does Line 3 execute? Predicted: Actual:

b) How many times does Line 6 execute? Predicted: Actual:

c) How many times does Line 8 execute? Predicted: Actual:

d) How many times does Line 10 execute? Predicted: Actual:

11. What determined how many times the "`for item`" loop would run?

12. Answer the following questions in terms of `grid`.

a) What determined how many times the "`for row`" loop would run?

b) What determined how many times the "`for cell`" loop would run?

13. Predict how many times the `print` statement will execute in the example below. Then run the code to verify your answer. Predicted: Actual:

```
for i in range(6):
    for j in range(7):
        print(i, '+', j, '=', i + j)
```

14. Rewrite the nested `for` loops in Model 2 Lines 4–10 using the `range` function. Replace the variables `row` and `cell` with `i` and `j`, respectively. For simplicity, you may omit the `print` statements in your answer.

15. Write a `for` loop (using `range`) that computes the factorial of a given integer n. Recall that $n! = n * (n-1) * (n-2) * \ldots * 1$. Store your result in a variable named `fact`.

16. Write nested loops that compute and display the factorial of each integer from 1 to 20. Use your code from the previous question as the inner loop. Your output should be in this format:

```
The factorial of 1 is 1
The factorial of 2 is 2
The factorial of 3 is 6
The factorial of 4 is 24
The factorial of 5 is 120
```

Model 3 Nested Dictionaries

Containers can be nested in arbitrary ways. For example, the following data could be described as a "dictionary of dictionaries of integers and lists of strings".

Enter the following code into a Python Shell, and complete the table. If the output is longer than one line, summarize it with a few words.

```
movies = {
    "Casablanca": {
        "year": 1942,
        "genres": ["Drama", "Romance", "War"],
    },
    "Star Wars": {
        "year": 1977,
        "genres": ["Action", "Adventure", "Fantasy"],
    },
    "Groundhog Day": {
        "year": 1993,
        "genres": ["Comedy", "Fantasy", "Romance"],
    },
}
```

Python code	Shell output
`movies`	
`movies["Casablanca"]`	
`movies["Casablanca"]["year"]`	
`movies["Casablanca"]["genres"]`	
`type(movies)`	
`type(movies["Casablanca"])`	
`type(movies["Casablanca"]["year"])`	
`type(movies["Casablanca"]["genres"])`	
`len(movies)`	
`len(movies["Casablanca"])`	
`len(movies["Casablanca"]["year"])`	
`len(movies["Casablanca"]["genres"])`	
`for key in movies:` `  print(key)`	
`for key, val in movies.items():` `  print(key, val)`	

Questions (15 min) Start time: _____

17. Explain the `TypeError` you encountered.

18. In the expression `movies["Casablanca"]["genres"]`, describe the purpose of the strings `"Casablanca"` and `"genres"`.

19. When iterating a dictionary using a `for` loop (i.e., `for x in movies`), what gets assigned to the variable?

20. What is wrong with the following code that attempts to `print` each movie?

```
for i in range(len(movies)):
    print(movies[i])
```

21. Write nested loops that output every *genre* found under the `movies` dictionary. You should have nine total lines of output.

22. Each movie in Model 3 has a title, a year, and three genres.

a) Is it necessary that all movies have the same format?

b) Name one advantage of storing data in the same format:

c) Show how you would represent The LEGO Movie (2014) with a runtime of 100 min and the plot keywords "construction worker" and "good cop bad cop".